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Monterey, California



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THESIS

DESIGN OF AN ENHANCED INTERACTIVE SATELLITE COMMUNICATIONS SYSTEM ANALYSIS PROGRAM

by

Kevin Robert Andersen

September 1991

Thesis Advisor: Donald v. Z. Wadsworth

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This thesis describes the design of a user-friendly interactive satellite communications analysis program for use on a personal computer. The user inputs the various parameters of a satellite orbit, ground station location and communications equipment. The output generated allows a user to view the satellite ground trace and footprint, calculate satellite rise and set times, and analyze the performance of the communications link. The link analysis allows the user to input various signal losses and jamming interference. Care was taken to ensure that the program is simple to operate and that it provides on-line help for each segment. A principle goal of this thesis effort is to provide an educational tool that familiarizes the user with the communications segment of a space system. The initial success of the program based upon student response validates the use of object-oriented like software tools that enhance user understanding of complex subjects.

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Design of an Enhanced Interactive Satellite
Communications System Analysis Program

by

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Lieutenant, United States Navy
B.S., United States Naval Academy, 1984

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This thesis describes the design of a user-friendly interactive satellite communications analysis program for use on a personal computer. The user inputs the various parameters of a satellite orbit, ground station location and communications equipment. The output generated allows a user to view the satellite ground trace and footprint, calculate satellite rise and set times, and analyze the performance of the communications link. The link analysis allows the user to input various signal losses and jamming interference. Care was taken to ensure that the program is simple to operate and that it provides on-line help for each segment. A principle goal of this thesis effort is to provide an educational tool that familiarizes the user with the communications segment of a space system. The initial success of the program based upon student response validates the use of object-oriented like software tools that enhance user understanding of complex subjects.

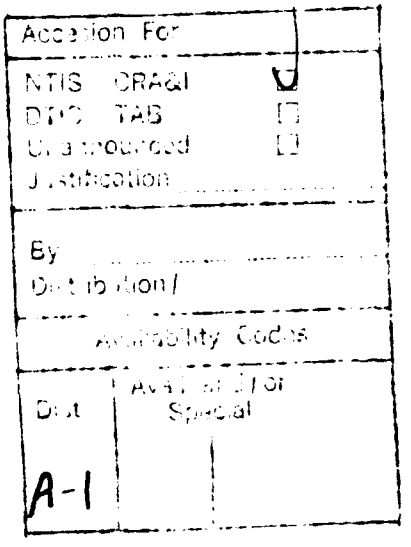


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I. INTRODUCTION

The role of space in the Navy took an important upturn on 1 August, 1990 when the Space and Electronic Warfare (SEW) Directorate, OP-094, was established as a directorate equal in status to the air, surface and undersea warfare communities. The crisis in the Persian Gulf that culminated in Operation 'Desert Storm' further validated the significance of space. Reliance on the Global Positioning System (GPS) for navigation data and satellite communications for command and control during 'Desert Storm' was evident to anyone who read a newspaper. As the utilization of space assets increases and the recognition of their importance grows, the need to educate the average junior officer on the various aspects of space systems becomes increasingly important. The goal of this thesis is to design an interactive, object-oriented like program, that will familiarize the user with one portion of a space system, the satellite communications system.

Many tools exist that will aid in the understanding of the complexity of a space system. Textbooks have always provided an academic orientation toward orbital mechanics and communications engineering. Software also exists that can provide a user with an efficient method to model the various parameters of a satellite or communications system. Often, the software and/or the systems on which they are designed to operate, are prohibitively expensive. The complexity of these tools may also require additional training to operate them effectively. It is therefore important that the program be designed to operate on relatively inexpensive equipment that requires minimal advanced training to operate. On-

line help should be available to assist the user in understanding program operation. Ideally, the program would be machine independent; i.e., the specific operating system of the computer should not be the limiting factor of the program.

The program designed for this thesis attempts to incorporate the requirements stated above. This program is designed to take advantage of the proliferation of personal computers. It assumes that the user is familiar with the basic operations of personal computers and has access to one. The chosen platform for the design of this program is the Macintosh personal computer and the development environment is HyperCard, version 2.0 or later. HyperCard and Macintosh are trademarks of Apple Computer, Inc., Cupertino, CA. HyperCard was chosen because of its ability to support rapid prototyping and because it comes bundled with every new Macintosh. Initially this restricts the use of the program to the Macintosh; however, software exists to convert this program to a comparable application that operates under the MS-DOS operating system.

This thesis outlines the development environment in Chapter II. The specific challenges encountered by the author during the design of this program are discussed in Chapter III. The program covers only a small part of a space system. The modular nature of the program allows for a great deal of growth. Recommendations for further study and conclusions are outlined in Chapter IV. This thesis does not include the actual program nor does it attempt to explain the operation of the program. A copy of each card in the stack is reproduced in Appendix A. The explanation of program operation and the equations utilized by the program are part of Appendix A, pages 62 to 128. Additionally, the significant scripts for the program are listed in Appendix B through F.

II. DESIGN ENVIRONMENT

A. HYPERCARD OVERVIEW

HyperCard is an object-oriented like application that comes with every new Macintosh. HyperCard is made up of five different types of objects: stacks, backgrounds, cards, fields and buttons. Each object contains its own specific properties and can contain its own code, referred to as a script, that can perform various functions based upon the transmission of system messages and the object's properties. The language utilized by HyperCard in the scripts is HyperTalk. HyperTalk is different from other languages, such as Basic or Pascal, in that there is no such thing as a HyperTalk program that controls the activities of HyperCard from beginning to end. Instead, it is the objects and their relationships to one another that determine the operation of the program. This relationship is based upon a concept of hierarchy. [Ref. 1, pp. 321-322]

B. HIERARCHY

The concept of hierarchy is critical to understanding the operation of HyperCard. An illustration of this concept is laid out in Figure 1. At the top of the hierarchy is the HyperCard application itself and at the bottom lie the buttons and fields. As HyperCard operates, a series of system messages are sent to the objects, depending on the current state of HyperCard. For example, if a user opens a HyperCard stack, an openStack message is sent from the stack up the hierarchy to HyperCard. When the stack opens, the first card in the stack is displayed and an openCard message is sent. When the user clicks the mouse, a

mouseUp message is sent. If the mouse click resides on a visible button, the message passes from the button up the hierarchy.

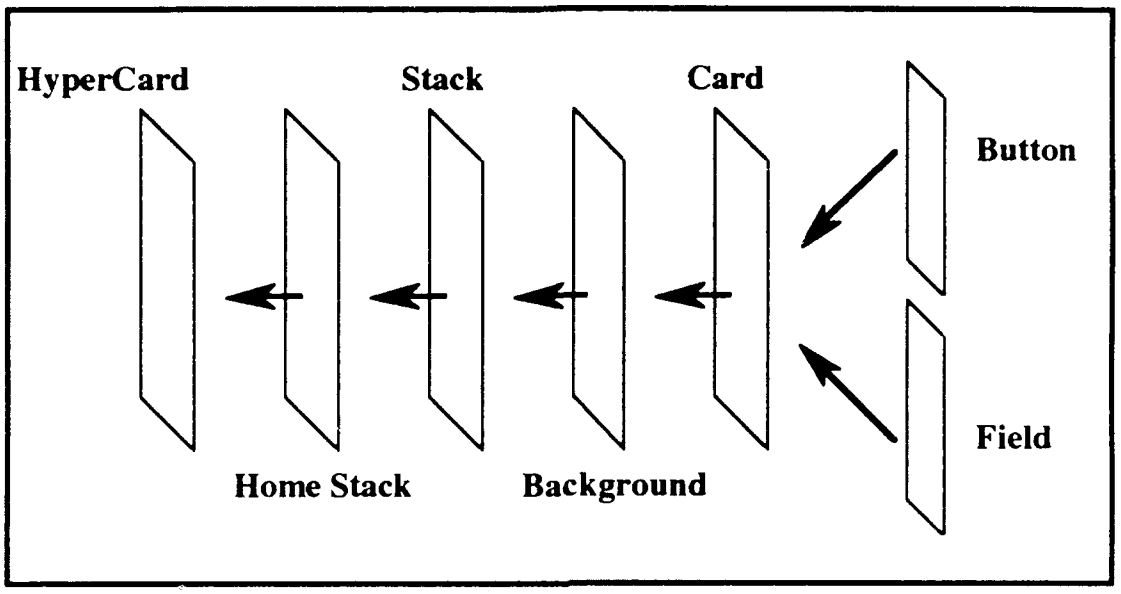


FIGURE 1. OBJECT HIERARCHY [Ref. 1, p. 341]

Scripts can be written for each object which will execute based upon these system messages. The scripts contain routines, referred to as handlers, that trap the system message at the desired object and execute a routine. These message handlers can contain additional handlers that will execute when called upon by name. These handlers must reside in the object or in the hierarchy above the object calling the handler. A card, for example, can call for a handler that resides in the card, its background, or the stack, but it may not call for a handler from a different card or from a field or button.

C. OBJECTS

As previously mentioned, HyperCard consists of five different objects: stacks, backgrounds, cards, buttons and fields. A stack may contain several backgrounds and multiple cards. Each background may have its own individual fields and buttons. Additionally, the background may contain various drawings or art work. Every card resides upon a background and each card can utilize the buttons, fields and art of the background in addition to its own fields, buttons and art. All of the objects in HyperCard can be quickly created or deleted as needed.

The stack can be visualized as a stack of 3 by 5 note cards. The card on the top of the stack is the one that is visible to the user. Through the manipulation of buttons and fields that contain the proper script, the user can access the cards in the stack in the order the stack designer desires. These navigation objects are normally activated by the click of the mouse.

Every object is identified by a specific identification number (id#) referenced to where it resides; for example, background button id 12 refers to a button that resides on a background whose id# is 12. Each object can also be given a name. This property is very useful as it allows the designer to refer to objects by their name. If the object's name is linked with the function of the object, the task of keeping track of object linkages becomes greatly simplified for the designer. It is also a method of self documenting the script so that an individual other than the designer can easily trace the operation of the script.

The ability to design into the program a specific route of navigation between objects makes a HyperCard stack modular. Scripts can reside in each object, a capability that further enhances the modularity of HyperCard [Ref. 1, pp. 321-322]. It is this modularity that makes HyperCard such an attractive

application. A single stack may contain several sections that accomplish a variety of different tasks. Outputs created by one section will remain alive in HyperCard as global variables and can be utilized, as needed, by any other section in the stack. Additionally, navigation between separate stacks is possible and the global variables created by one stack may be used by any other stack as long as HyperCard itself is active.

D. HYPERTALK

HyperTalk is a high level programming language. As a language it has structure and syntax that must be adhered to. Unlike other languages though, it is very liberal in its structure and syntax. For example, the command "go next" would cause HyperCard to bring the next card in the stack to the top. The command "go to next card" does the same thing. The forgiving nature of the language is the ideal environment for novice programmers. This statement should not be misconstrued, as HyperCard is also an excellent environment for prototyping very sophisticated applications that require advanced programming skills.

The scripts, which will execute based upon the transmission of system messages, contain commands for the manipulation of objects, built in and user defined functions, and key words that will execute user defined handlers when called. The ability for the user to define special functions and handlers is a tremendous asset, but care must be exercised to follow the hierarchy rules when defining the functions and handlers.

For designers with experience in advanced programming, HyperCard offers unlimited expandibility through the use of exterior commands (XCMD) and

exterior functions (XFCN). XCMDs and XFCNs are separate programs written and compiled in a language such as Pascal and are intended to add a capability that does not already exist. These XCMDs and XFCNs can the be attached as a resource to the stack for which they are intended. They can then be called upon by a script in the same manner as built in functions and commands. [Ref. 1, pp. 750-751]

The ability to attach resources to HyperCard allows for the development of multi-media stacks, i.e., stacks that provide text, graphics, audio and video presentations. For example, software exists that can record and digitalize audio and convert it into a resource. This thesis does not take advantage of XCMDs, XFCNs, or audio and video resources but they are mentioned here for follow on considerations.

For access to the scripts the designer must set the property userLevel to five. From here the designer can open the script windows for each object. The script windows display the object's script under the script editor. The script editor allows a debugging capability that is useful in tracing the operation of complicated scripts. The script editor also automatically indents all control structures (if-then and repeat statements), a format that can aid the designer in debugging.

HyperCard does not compile, but instead interprets the scripts as it is executed. The interpreted script remains in HyperCard's portion of the random access memory (RAM) as long as the RAM has room for it. When another script is interpreted, it too is added to the RAM and if there is no more room, previously interpreted scripts are deleted from the RAM. The designer is thus encouraged to take advantage of the modular nature of HyperCard and write frequently called

routines as separate, smaller handlers. These smaller handlers will remain in the RAM longer, thus increasing the speed of the program. Allotting more RAM for HyperCard will allow more scripts to remain interpreted, increasing the program's efficiency. [Ref. 1, pp. 336-337]

III. DESIGN CHALLENGES

A. GENERAL SCOPE

As delineated in the introduction, the goal of this thesis is to design an interactive, object-oriented like program, that will allow the average junior officer to better understand the basics of a satellite communications system. The attributes of HyperCard, as outlined in Chapter II, meet the object-oriented like requirement. Thus arises the challenge of implementing HyperCard to model a satellite communications system. For the purpose of this thesis, the systems in question are communications with existing, stable satellites that reside in a closed earth orbit; i.e., communications with interplanetary probes were not addressed.

This chapter will not attempt to describe the operation of the program nor does it outline the equations or the algorithms used by the scripts during their execution. A tutorial on the program operation and equations used is contained in Appendix A, pages 62 to 128. The significant scripts written for the stack are reproduced in Appendix B through E.

The analysis of a communications system can be broken into three primary parts. The first part requires knowledge of the orbital elements of the satellite in question. The second requires information on the ground station's location and existing climate. The third section requires knowledge of the basic parameters associated with the communications equipment. It is important that the user be able to visualize how these three parts relate to one another. Three outputs were developed, based upon user inputs, that allow the user to visualize the relationships of these parts. The first output allows the user to see a ground trace

of the satellite as it orbits the earth. The second output allows the user to determine when the satellite comes into view of the ground station and the third output allows the user to analyze the performance of the communications equipment. At each stage in the operation the user is invited to adjust the various inputs and analyze their effect on the output.

B. GROUND TRACE

The ability of the user to visualize the ground trace of the satellite is probably the most important tool in understanding the operation of a satellite. Thus, the first major challenge in the design of the program was to give the user that capability. The physics involved in the determination of a satellite's position on orbit are not difficult and the average junior officer has the education required to understand the process. The problem arises in transferring that orbital position, which resides in one coordinate system, to a map of the earth, which resides in another coordinate system. The user should also be able to visualize a footprint on the ground of what the satellite can see. Additionally, the user should be able to display the ground trace and footprint of the satellite on a detailed map.

Traditionally, the orbit of a satellite is based upon an earth-centered inertial coordinate system. A location on the surface of the earth is referenced to another system. Tying these two coordinate systems together requires a coordinate transformation. The specific algorithm for this process was adapted from the work of Dennis Wangsness [Ref. 2]. This algorithm allows the program to plot the ground track of the orbit on a world map. The world map in question resides on the background of a card. The process that the program uses to display the ground trace is to copy the card with the world map and paste it, draw the

ground trace and then repeat the routine. The script for this process is located in Appendix E, pages 205 to 209, and the associated handlers are in Appendix B, pages 130 to 136.

The footprint of the satellite is a function of the satellite's altitude above the earth and of the ground station's minimum antenna elevation. The ability to model the specifics of the satellite antenna exists but was not included in this thesis. Once again, a coordinate transformation is required. The algorithm for this process was adapted from the work of Dennis Wangsness [Ref. 2]. The scripts for this process are located in Appendix E, pages 205 to 209, and the associated handlers are in Appendix B, pages 130 to 136.

Perhaps the greatest challenge was locating maps that could provide accurate detail of specific locations on the earth. Many maps exist on computer shareware that could provide the required detail, but they could not be used because their geographic parameters were unknown. In order for the maps to work with the existing scripts, the latitude separation must be the same at any location on the map. That same property must hold true for the longitude. This type of map is known as a rectangular projection and is the type of projection used by the world map. While this type of projection on a small scale map causes significant distortions at higher latitudes, the distortions are minimal on a large scale map. The maps were generated by a product called MicroCam [Ref. 3]. MicroCam allows the user to select the desired projection, the center point of the map and the corner points. The maps are then scanned into the program stack. Once the maps with the proper projection were obtained, scaling them to fit the ground trace algorithm was relatively simple. The maps used for this program are

depicted in Appendix A, pages 48 to 62. The scaling parameters are listed in Appendix E, pages 210 to 214.

C. RISE AND SET

It is important to understand that, in most cases, a satellite does not hover overhead a ground station like a helicopter. The only time this is true is if the satellite is in a geostationary orbit. Depending upon the space system analyzed, this orbit may be prohibitive to the satellite's mission. In all other cases, the satellite will appear to the ground station to rise and set in the sky much like the sun or the moon. In order for the user to visualize how the orbital parameters and ground station location can impact access to the satellite, an ability to determine the rise and set times of the satellite must exist. A geostationary satellite is treated as a special case by the program and is always considered in view.

The solution for the rise and set times again involve coordinate transformations, as described above, and the transposition of the satellite position vector onto the ground station position vector. When the magnitude of the resultant vector exceeds the radius of the earth, the satellite is considered to be above the ground station's horizon.

In order to increase the accuracy of the program, allowances are made for the oblateness of the earth. The Earth's radius at the equator exceeds its radius at the poles by about 21 kilometers. This fact could alter the rise and set times by several minutes if not accounted for. The genesis for the algorithm that provides the solution for the rise and set times was provided by the work of William Zeleny [Ref. 4]. The actual script is reproduced in Appendix E, pages 184 to 187, and the associated handlers are in Appendix B, pages 130 to 136.

D. LINK PERFORMANCE

The performance of a communications link is a function of not only the equipment involved but also the range between the stations, atmospheric conditions, distance travelled in the atmosphere and the frequency utilized. This list is not all inclusive but is indicative of the parameters modeled by the program. In order to visualize these parameters and their effect on one another, a spreadsheet type format was used. Once the display is generated, the user can quickly modify the inputs and analyze the impact. The most difficult element to model was the attenuation of the signal due to rainfall. The prediction of this attenuation is dependent on the local climatic conditions of the ground station.

The prediction of climatic conditions is not an easy venture. Rainfall rates and intensities and the altitudes from which the rain begins vary throughout the world. In order to simplify the process the Crane Global Rain model was adapted to the program. The Crane model was used because it is fairly accurate, easy to implement, and exists in many texts and handbooks that cover the topic of communications [Ref. 5, pp. 157-165]. The Crane model identifies eight major climate regions on the earth and establishes twelve different rainfall rates based upon the percentage of time over one year that the rainfall rate is exceeded.

Selection of the Crane model provided the solution to one piece of the puzzle. The second problem was identifying which climate region corresponded to the geographic location of the ground station in question. The solution was to trap the system message "mouseUp" on a button that identified the climate region. The buttons that contain this script overlay a global map of the earth. This particular card is provided to the user for entry of the ground station directly on the screen. The card and associated map and buttons were adapted from the

work of Charles Howard [Ref. 6]. The scripts that calculate the rain attenuation are in Appendix E, pages 189 to 191, and the associated handlers are in Appendix C.

IV. RECOMMENDATIONS AND CONCLUSIONS

A. RECOMMENDATIONS

The program developed for this thesis models the satellite communications element of a space system. Additional topic areas that for communications systems include:

- Signal attenuation due to atmospheric conditions such as: atmospheric dust, presence of clouds and fog, and smoke.
- Communications via relay satellites
- Modelling the actual satellite antenna characteristics and resultant satellite footprint.
- Doppler shift induced by satellite motion
- Spread spectrum technology
- Digital coding, bit error rates and coding gains

These are areas of concern that are important in understanding how a satellite communications system works.

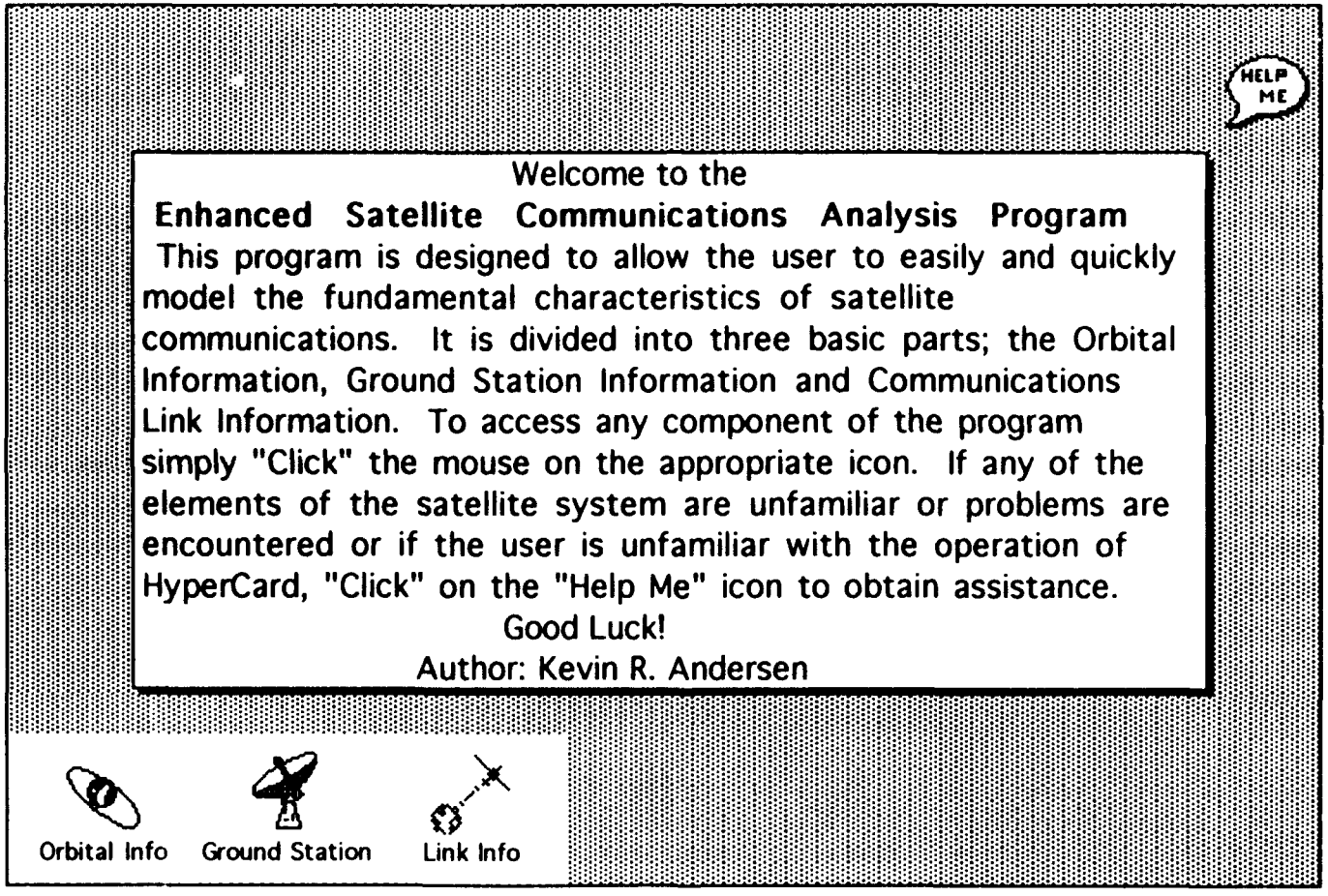
Additional space system topics that would complement this thesis are:

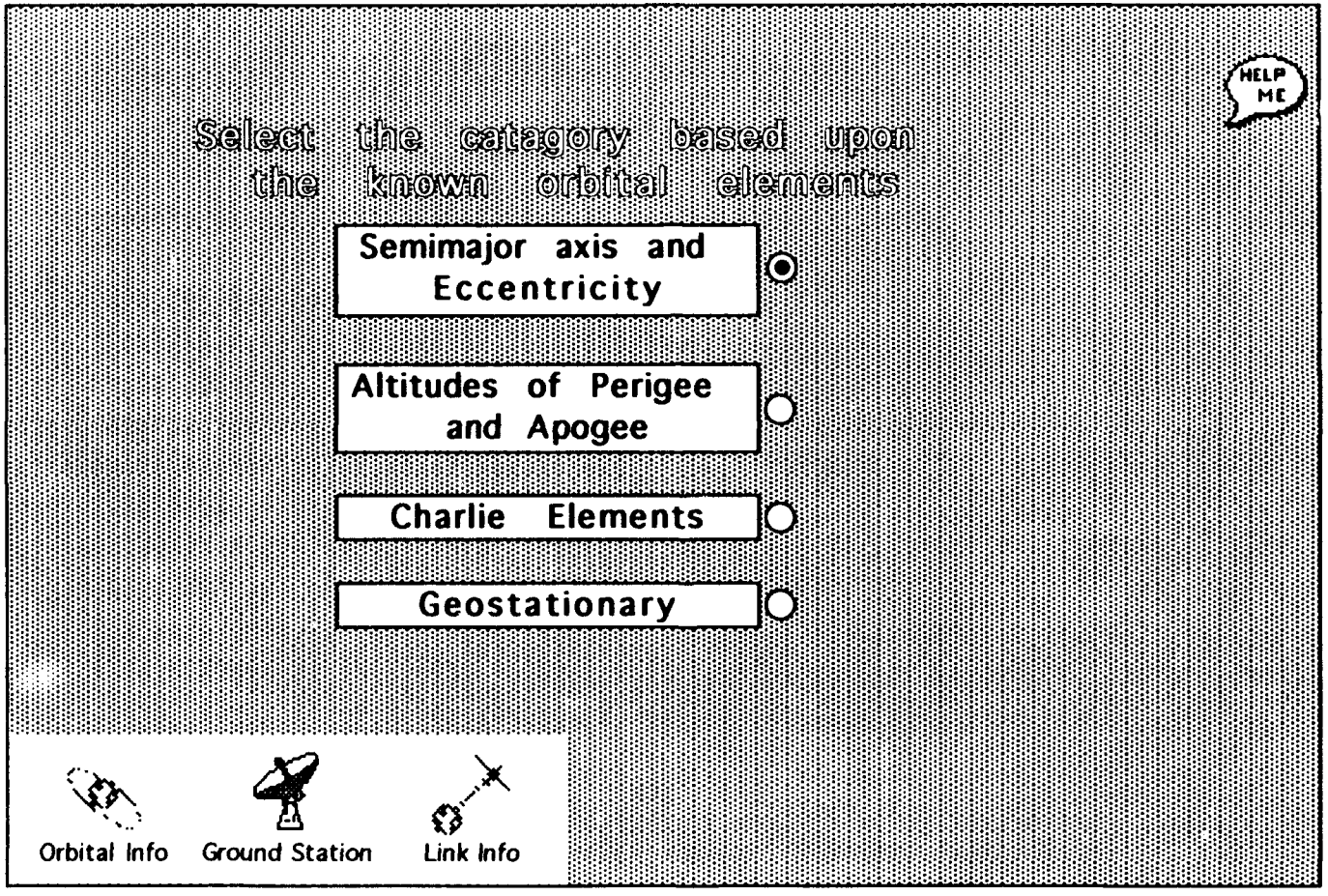
- Ascent trajectory from launch to orbital insertion
- Effects of orbital perturbations
- Satellite subsystem breakdown and subsystem operation for a generic three axis or spin stabilized satellite.
- Control and tasking of a satellite or satellite constellation.

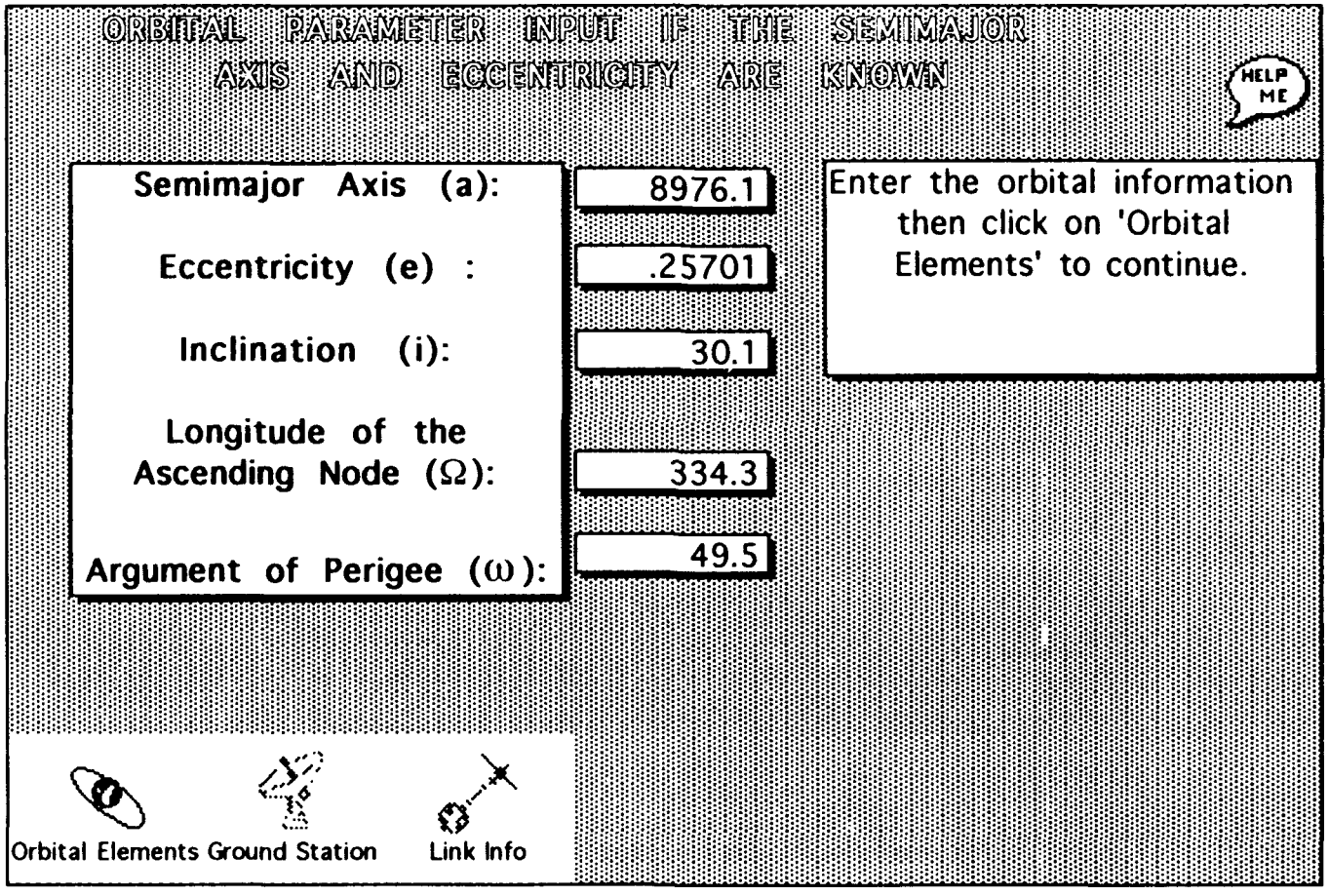
These areas of interest could be developed as separate modules of the original program and, utilized as a whole, would provide valuable education in the operation of a space system.

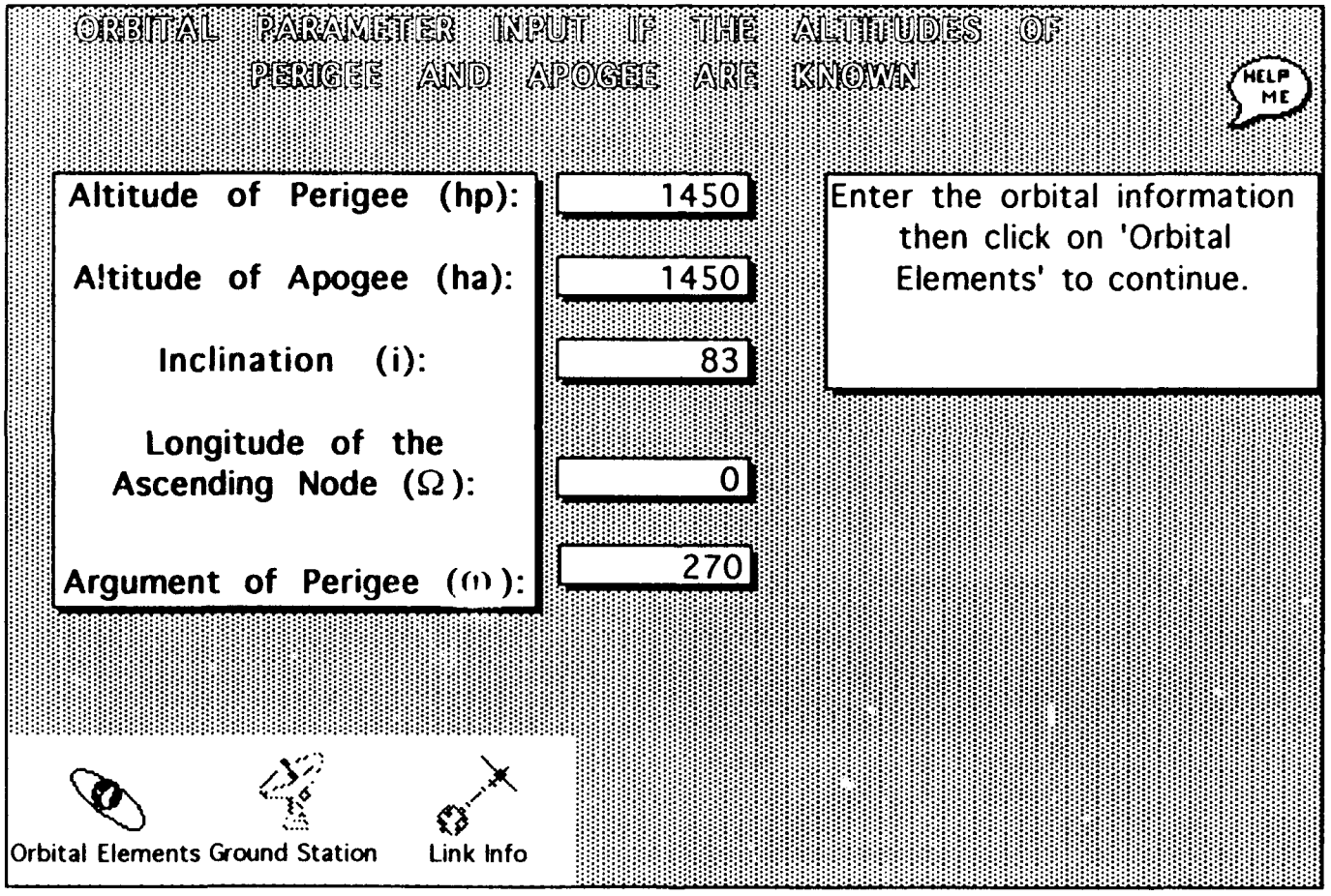
B. CONCLUSION

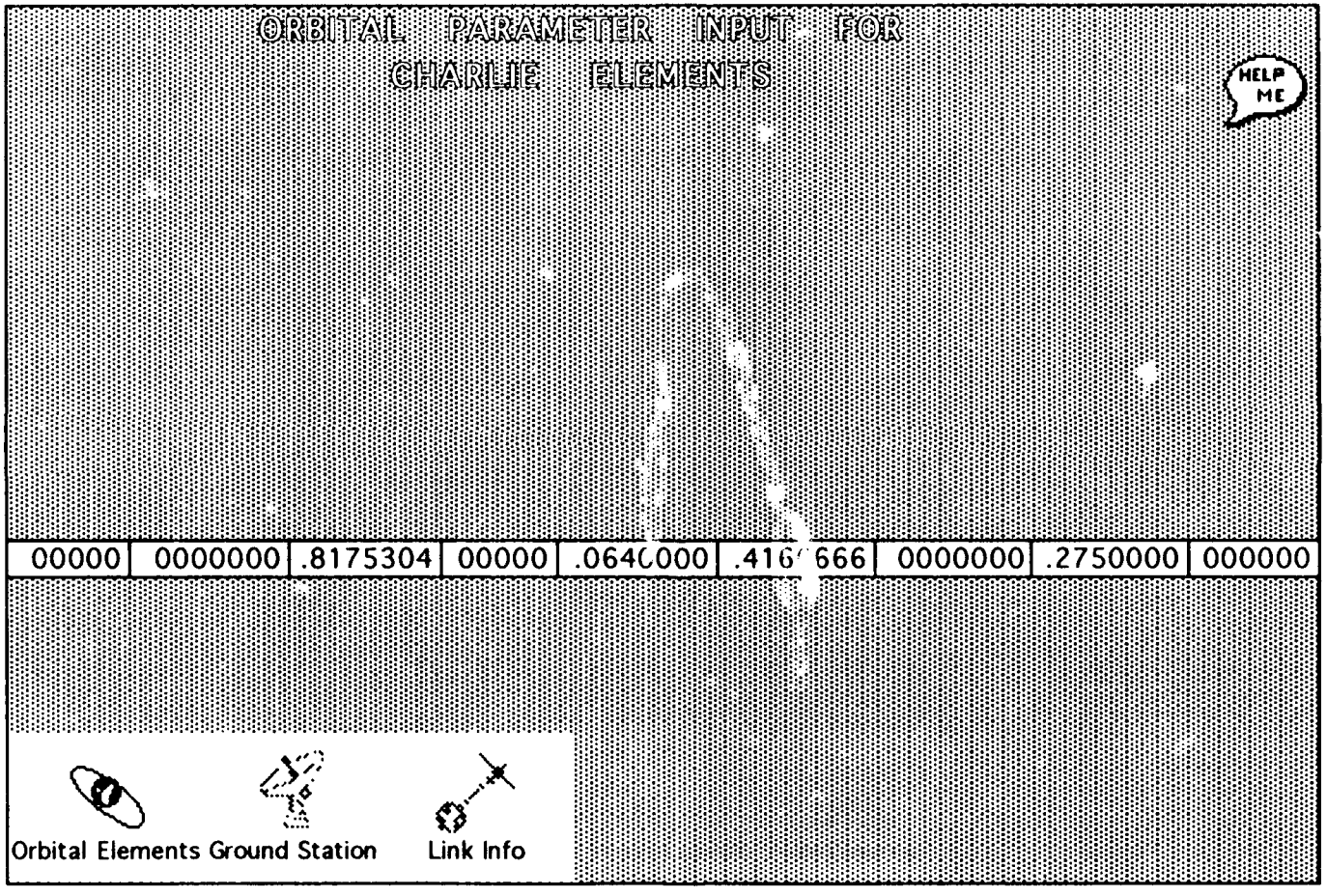
The program developed for this thesis demonstrates that educational tools can be developed that provide comprehensive insight into the operation of a complex system. The interactive design of the program forces the user to become involved with the process, thus learning by doing. The object-oriented like nature of HyperCard and the included on-line help allow the user to operate the program with minimal training. The specific topic of the program attempts to remedy an educational shortfall in an increasingly vital area.

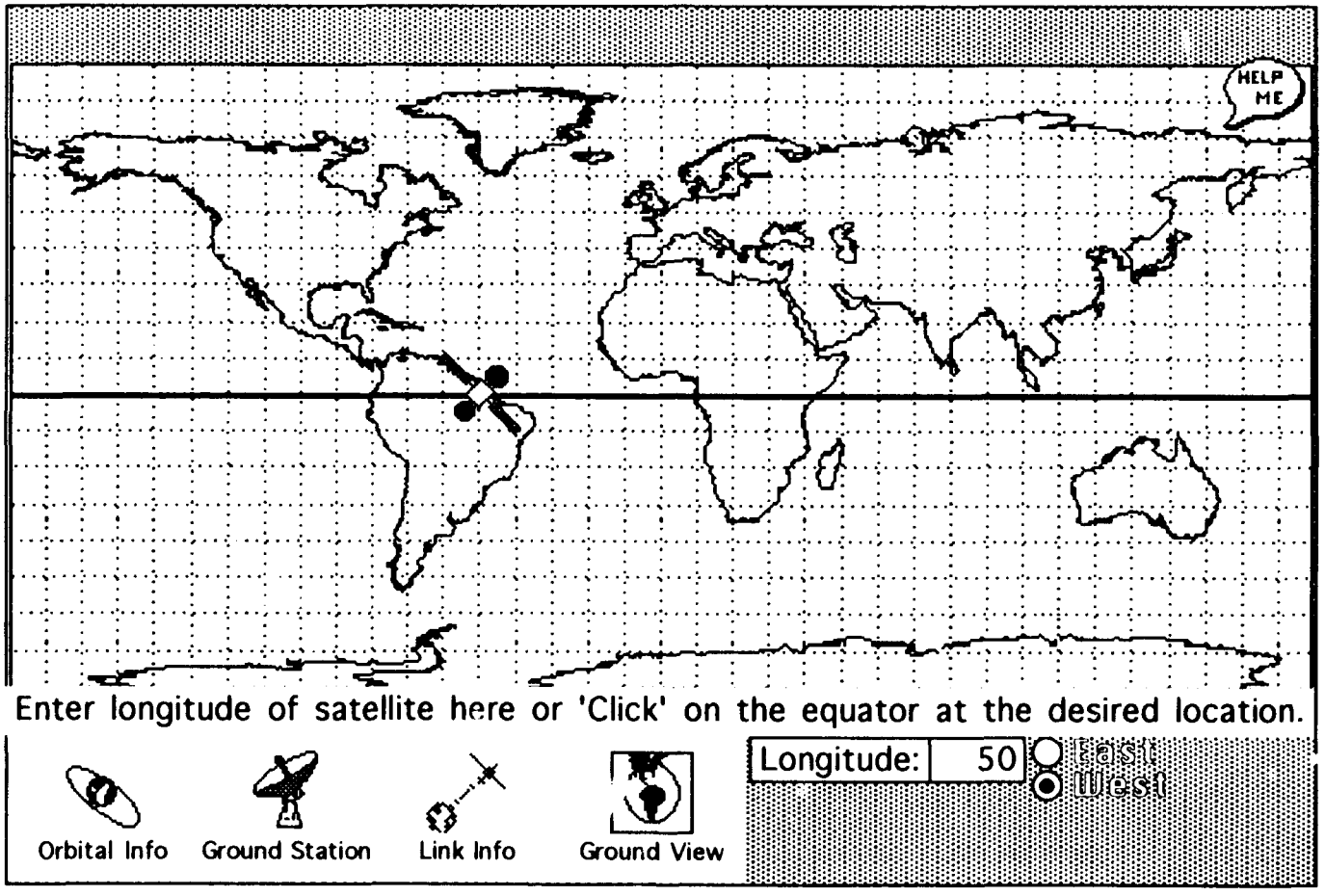

HELP ME
Welcome to the
Enhanced Satellite Communications Analysis Program
This program is designed to allow the user to easily and quickly model the fundamental characteristics of satellite communications. It is divided into three basic parts; the Orbital Information, Ground Station Information and Communications Link Information. To access any component of the program simply "Click" the mouse on the appropriate icon. If any of the elements of the satellite system are unfamiliar or problems are encountered or if the user is unfamiliar with the operation of HyperCard, "Click" on the "Help Me" icon to obtain assistance.
Good Luck!
Author: Kevin R. Andersen
Orbital Info
Ground Station
Link Info

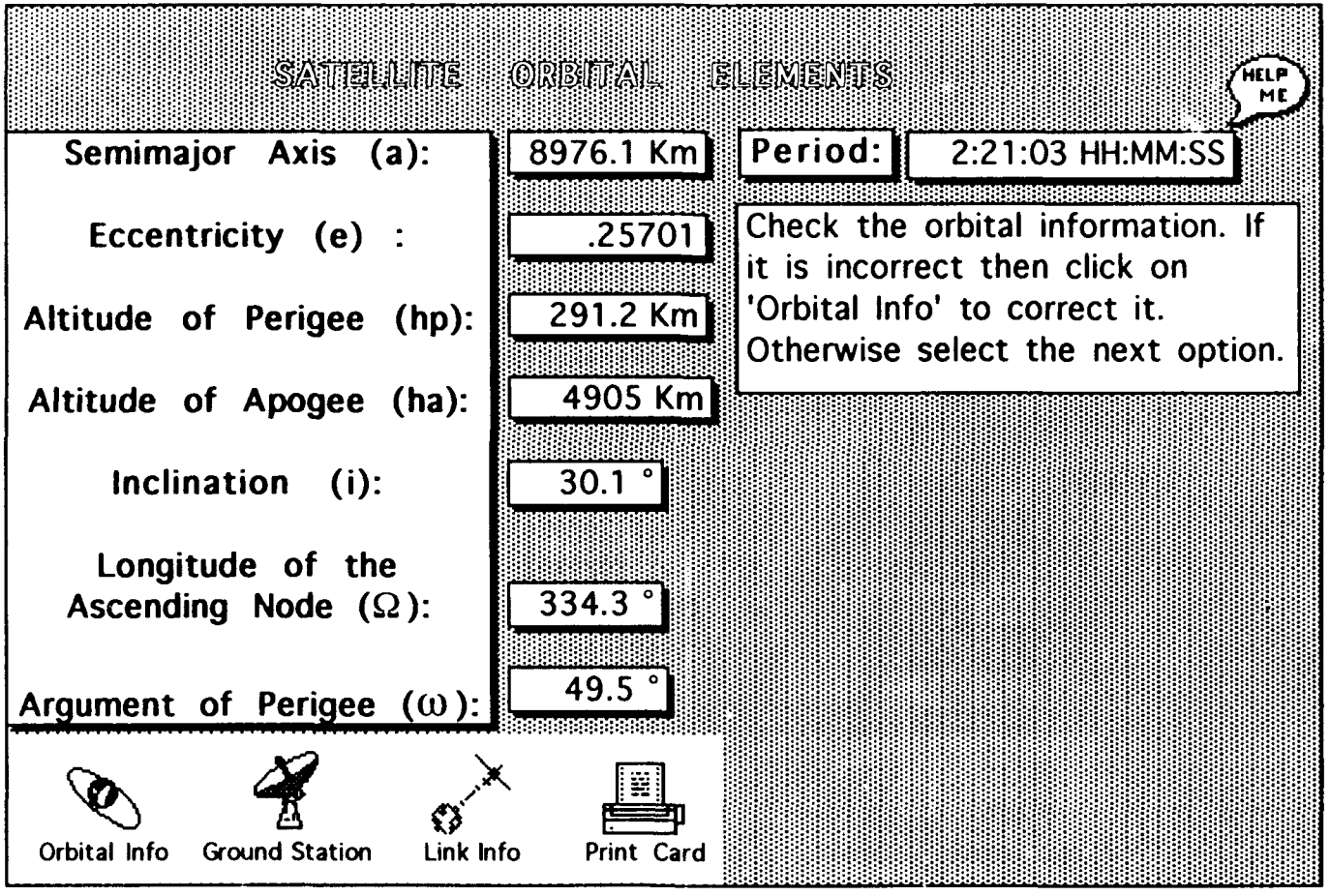

HELP ME
Select the catagory based upon the known orbital elements
Semimajor axis and Eccentricity
Altitudes of Perigee and Apogee
Charlie Elements
Geostationary
Orbital Info
Ground Station
Link Info

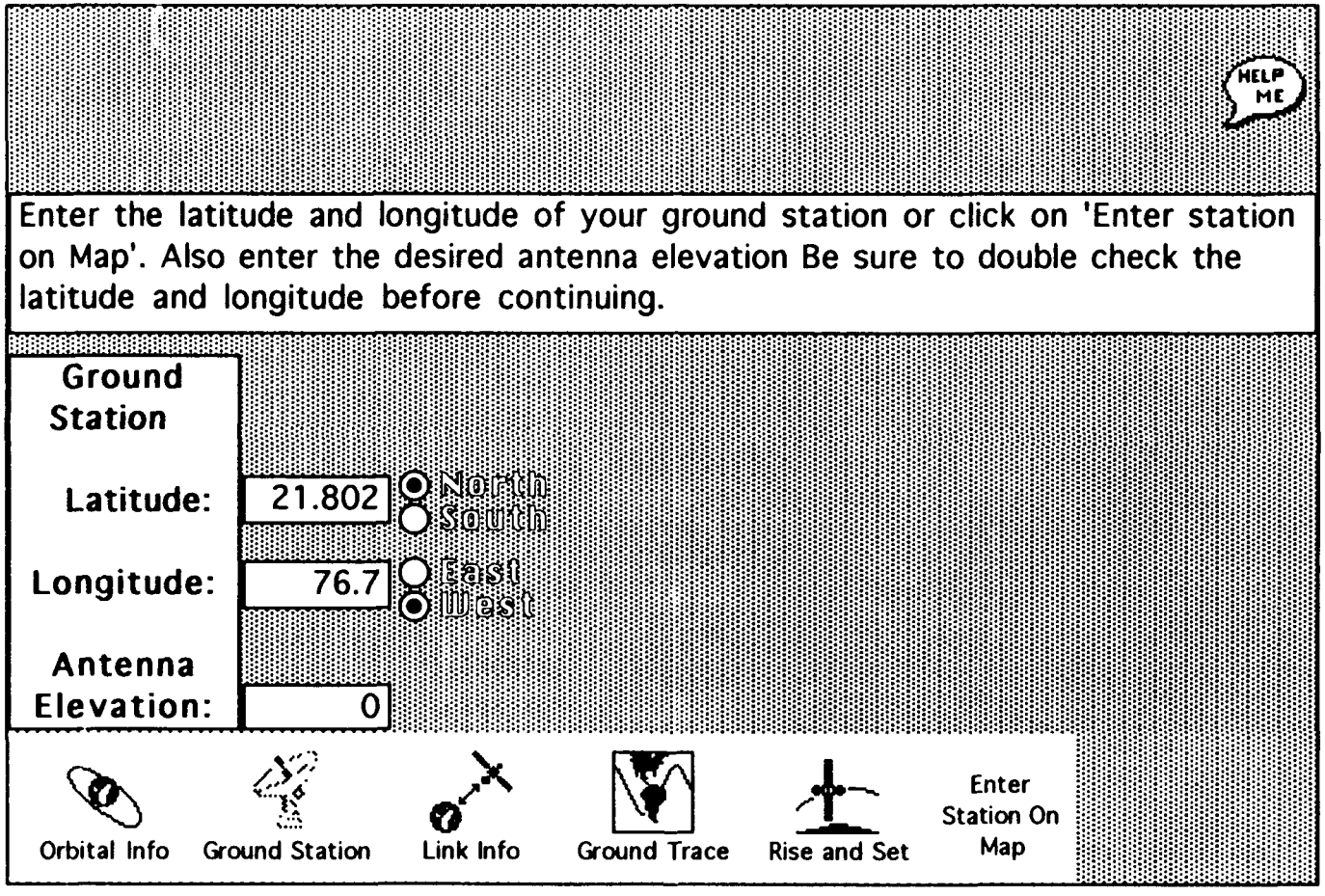

ORBITAL PARAMETER INPUT IF THE SEMIMAJOR AXIS AND ECCENTRICITY ARE KNOWN
HELP ME
Semimajor Axis (a):
8976.1
Eccentricity (e) :
.25701
Inclination (i):
30.1
Longitude of the Ascending Node (Ω):
334.3
Argument of Perigee (ω):
49.5
Enter the orbital information then click on 'Orbital Elements' to continue.
Orbital Elements
Ground Station
Link Info

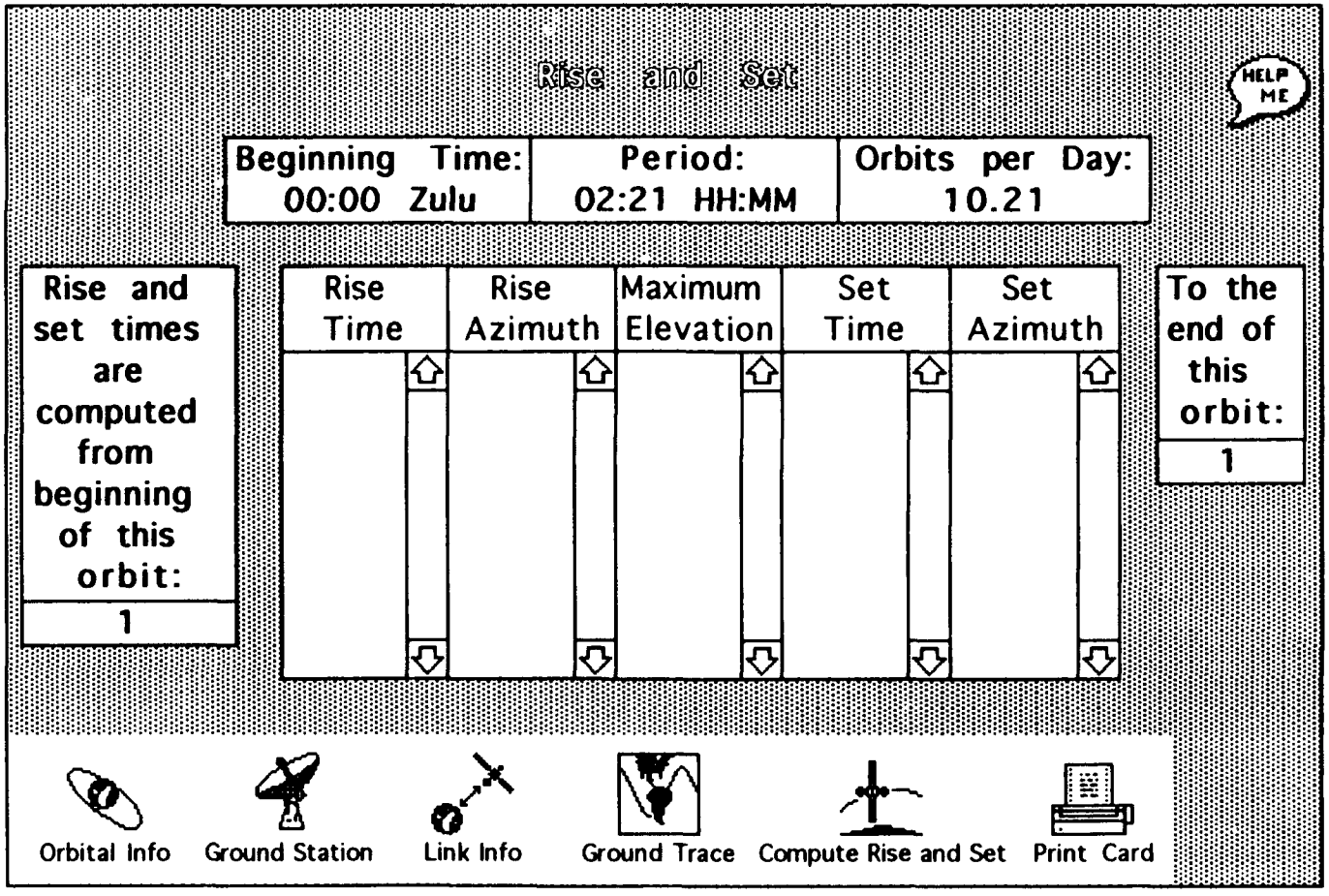

ORBITAL PARAMETER INPUT IF THE ALTITUDES OF PERIGEE AND APOGEE ARE KNOWN
HELP ME
Altitude of Perigee (hp):
1450
Altitude of Apogee (ha):
1450
Inclination (i):
83
Longitude of the Ascending Node (Ω):
0
Argument of Perigee (ω):
270
Enter the orbital information then click on 'Orbital Elements' to continue.
Orbital Elements
Ground Station
Link Info

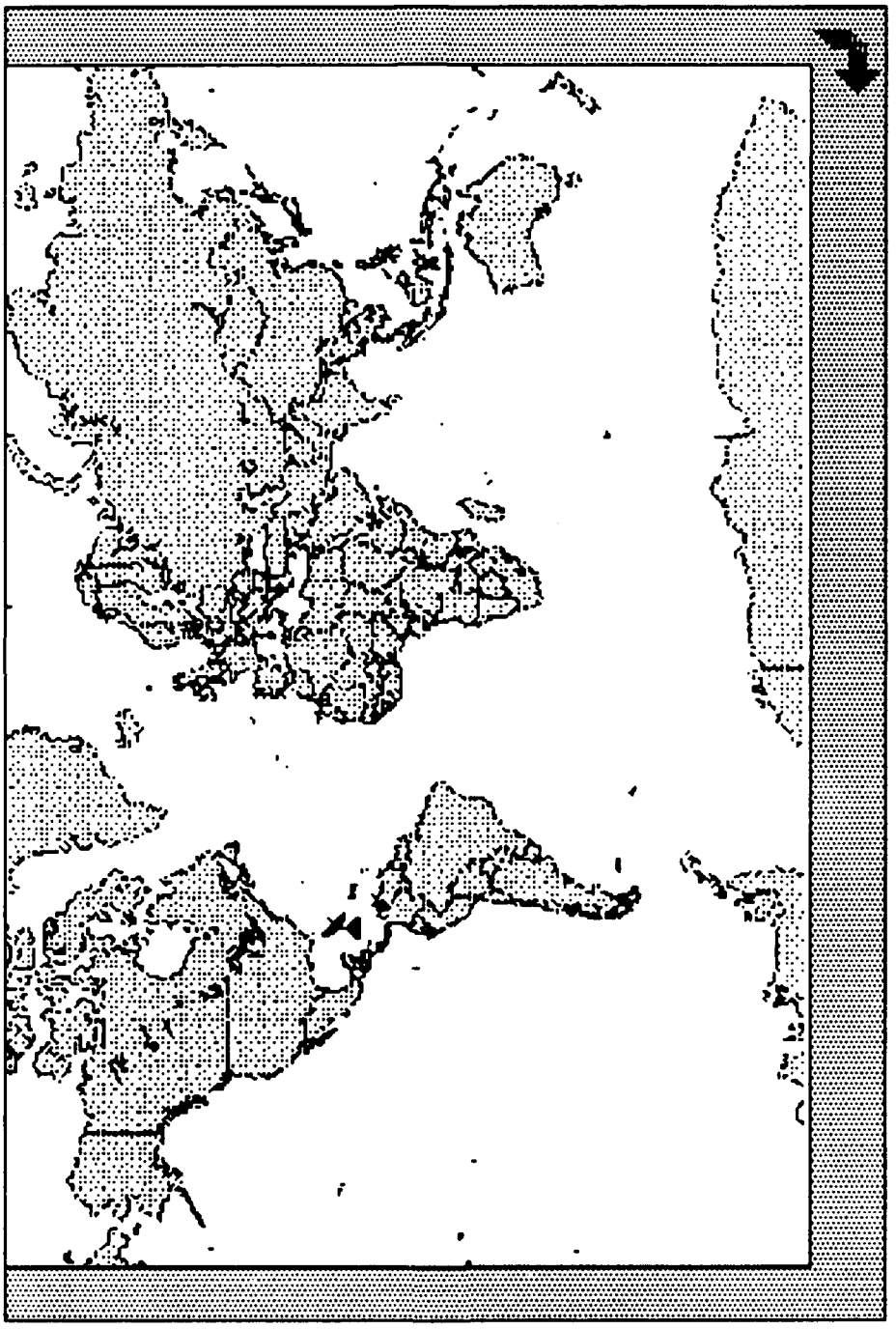

ORBITAL PARAMETER INPUT FOR
CHARLIE ELEMENTS
HELP ME
00000
0000000
.8175304
00000
.0640000
.4166666
0000000
.2750000
000000
Orbital Elements
Ground Station
Link Info

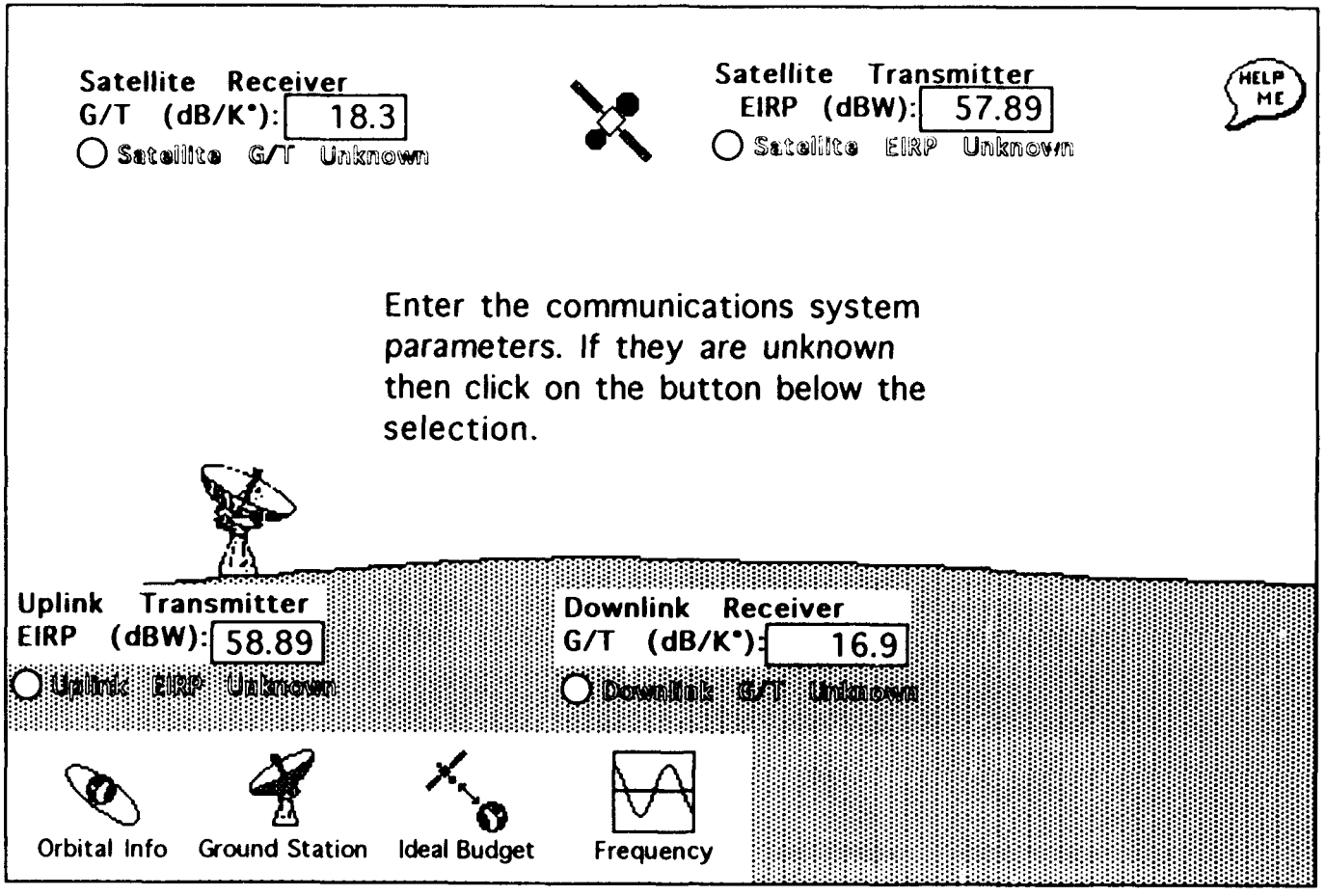

HELP ME
Enter longitude of satellite here or 'Click' on the equator at the desired location.
Orbital Info
Ground Station
Link Info
Ground View
Longitude:
50
East
West

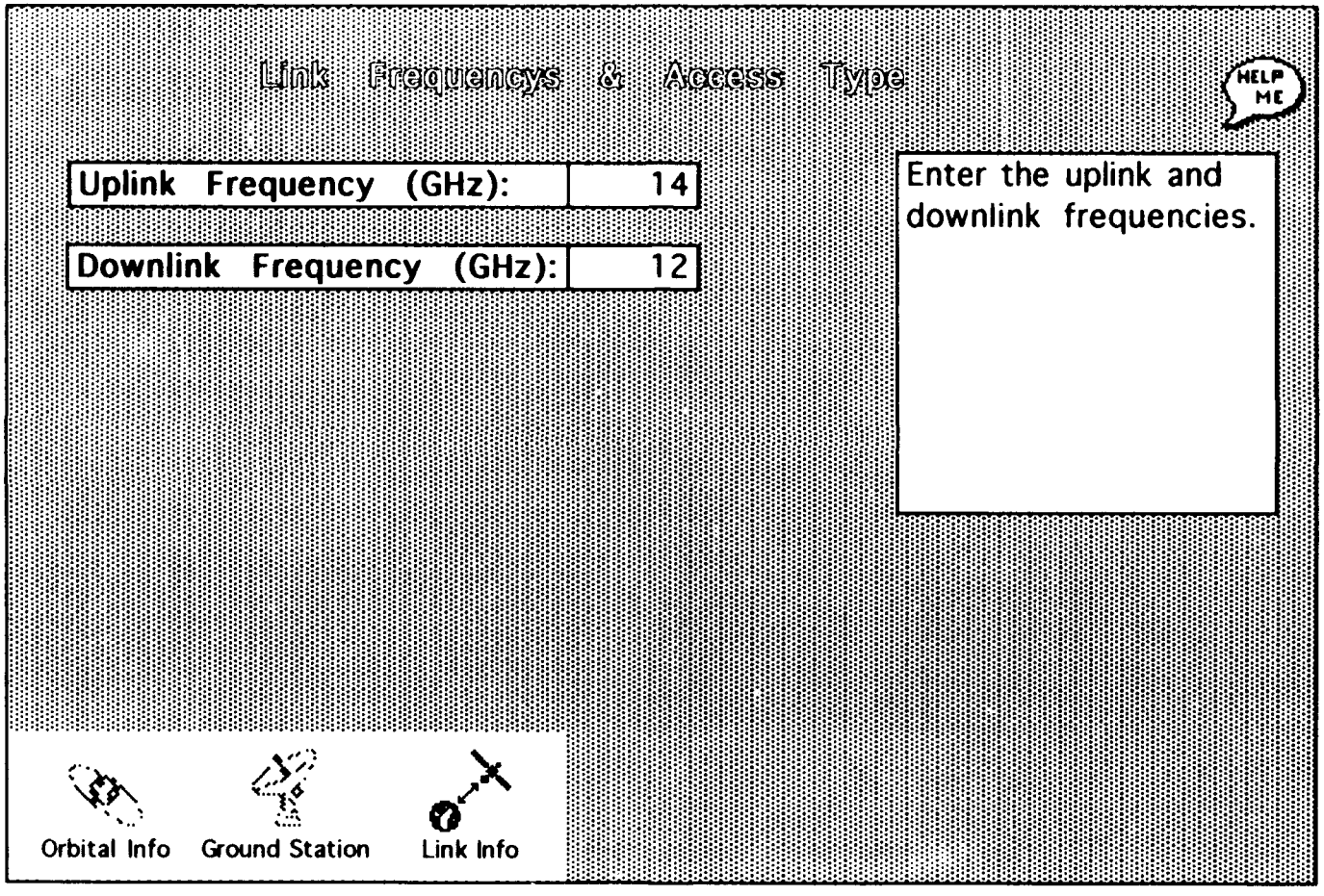

SATELLITE ORBITAL ELEMENTS
HELP ME
Semimajor Axis (a):
8976.1 Km
Period:
2:21:03 HH:MM:SS
Eccentricity (e) :
.25701
Check the orbital information. If it is incorrect then click on 'Orbital Info' to correct it. Otherwise select the next option.
Altitude of Perigee (hp):
291.2 Km
Altitude of Apogee (ha):
4905 Km
Inclination (i):
30.1 °
Longitude of the Ascending Node (Ω):
334.3 °
Argument of Perigee (ω):
49.5 °
Orbital Info
Ground Station
Link Info
Print Card

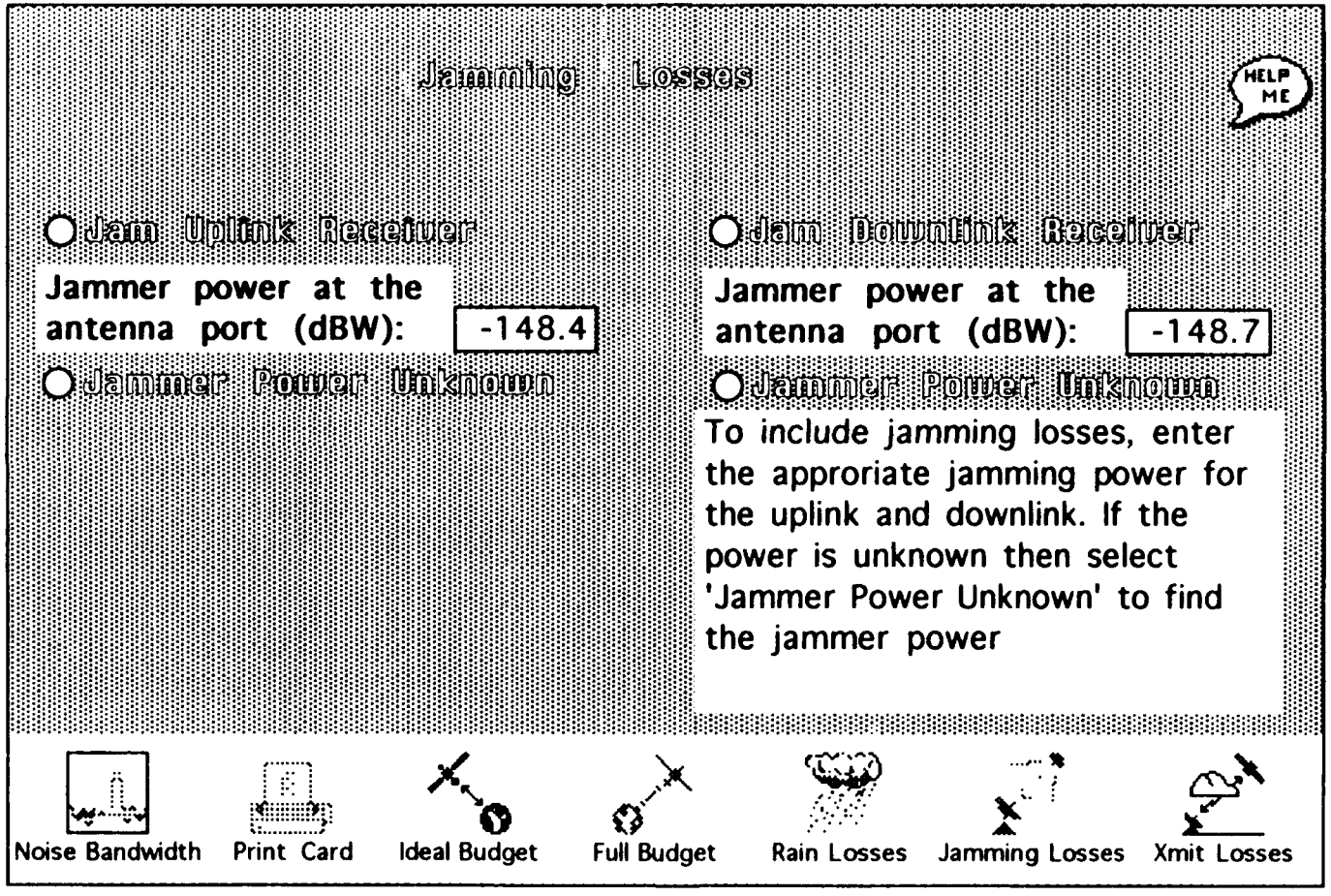

HELP ME
Enter the latitude and longitude of your ground station or click on 'Enter station on Map'. Also enter the desired antenna elevation Be sure to double check the latitude and longitude before continuing.
Ground Station
Latitude:
21.802
North
South
Longitude:
76.7
East
West
Antenna Elevation:
0
Orbital Info
Ground Station
Link Info
Ground Trace
Rise and Set
Enter Station On Map

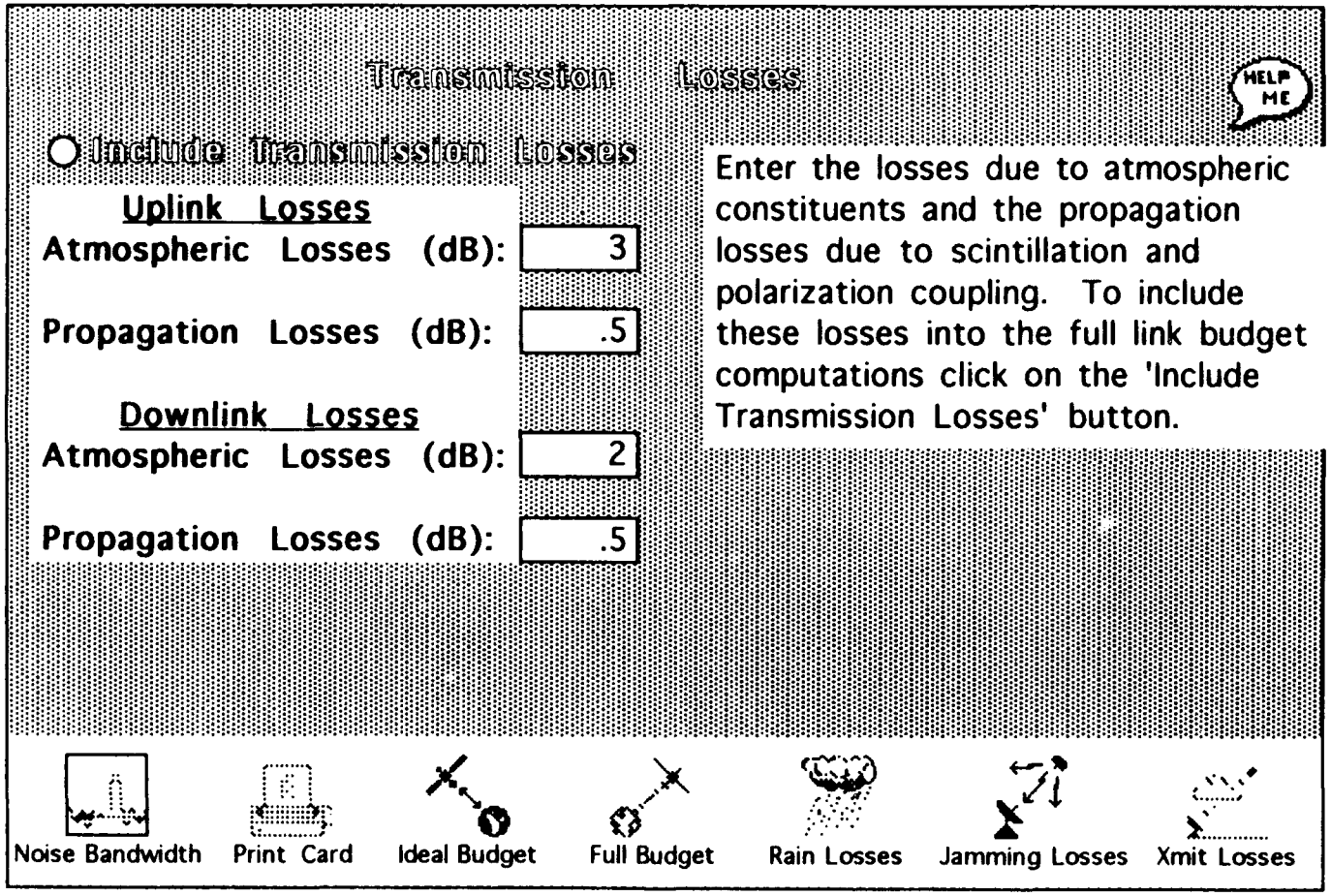

Rise and Set
HELP ME
Beginning Time:
00:00 Zulu
Period:
02:21 HH:MM
Orbits per Day:
10.21
Rise and set times are computed from beginning of this orbit:
1
Rise Time
Rise Azimuth
Maximum Elevation
Set Time
Set Azimuth
To the end of this orbit:
1
Orbital Info
Ground Station
Link Info
Ground Trace
Compute Rise and Set
Print Card

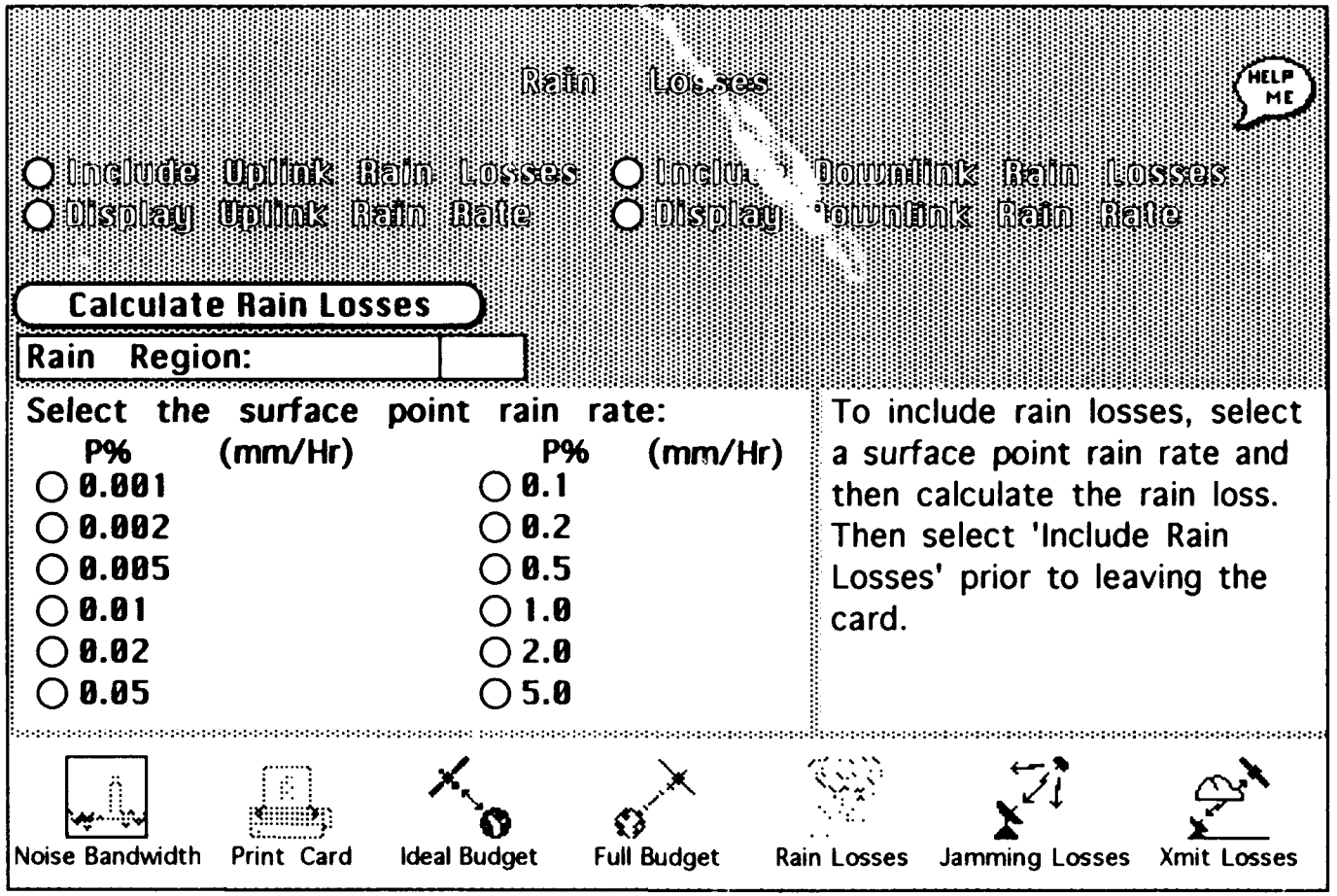


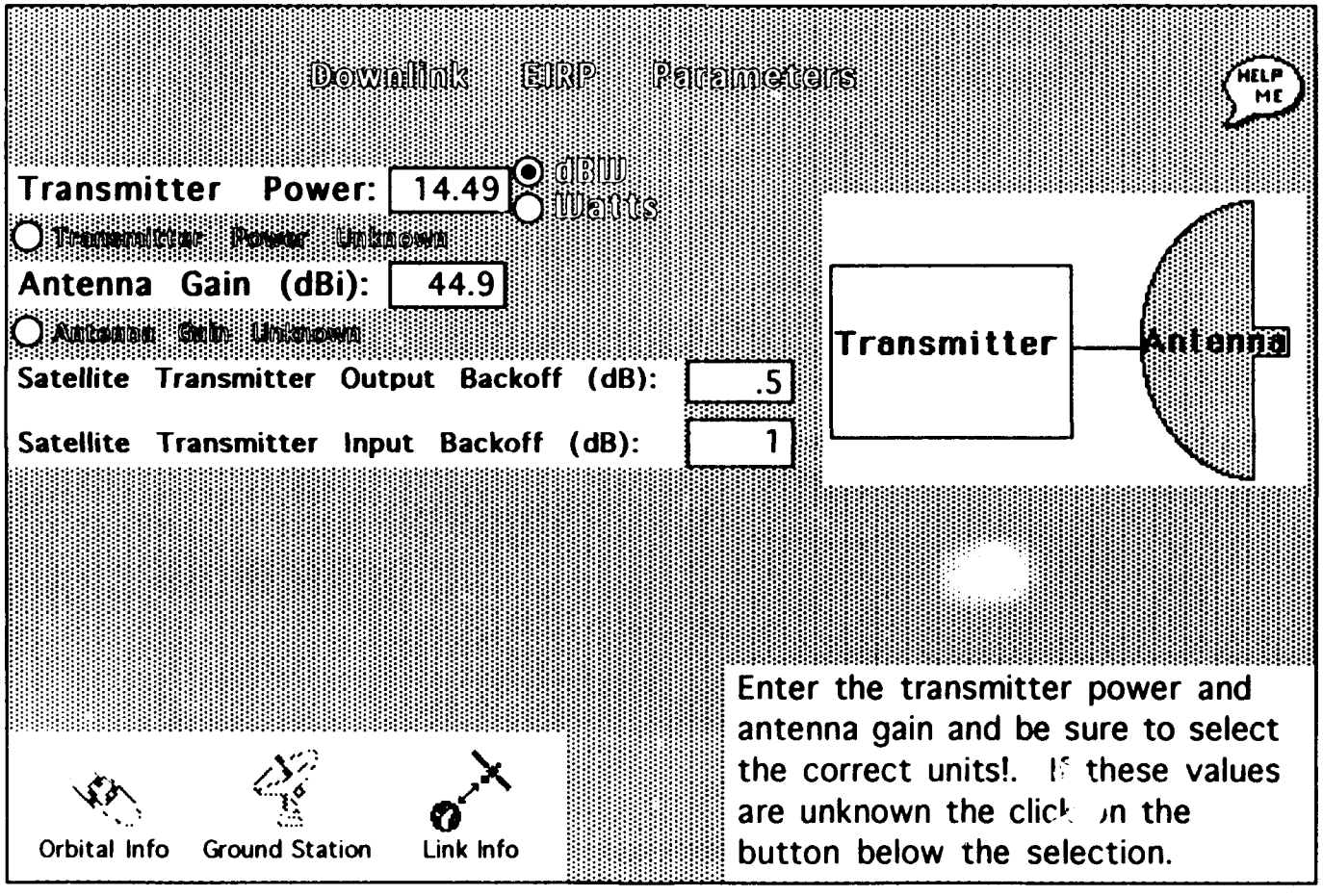

Satellite Receiver
G/T (dB/K°): 18.3
Satellite G/T Unknown
Satellite Transmitter
EIRP (dBW): 57.89
Satellite EIRP Unknown
HELP ME
Enter the communications system parameters. If they are unknown then click on the button below the selection.
Uplink Transmitter
EIRP (dBW): 58.89
Uplink EIRP Unknown
Downlink Receiver
G/T (dB/K°): 16.9
Downlink G/T Unknown
Orbital Info
Ground Station
Ideal Budget
Frequency

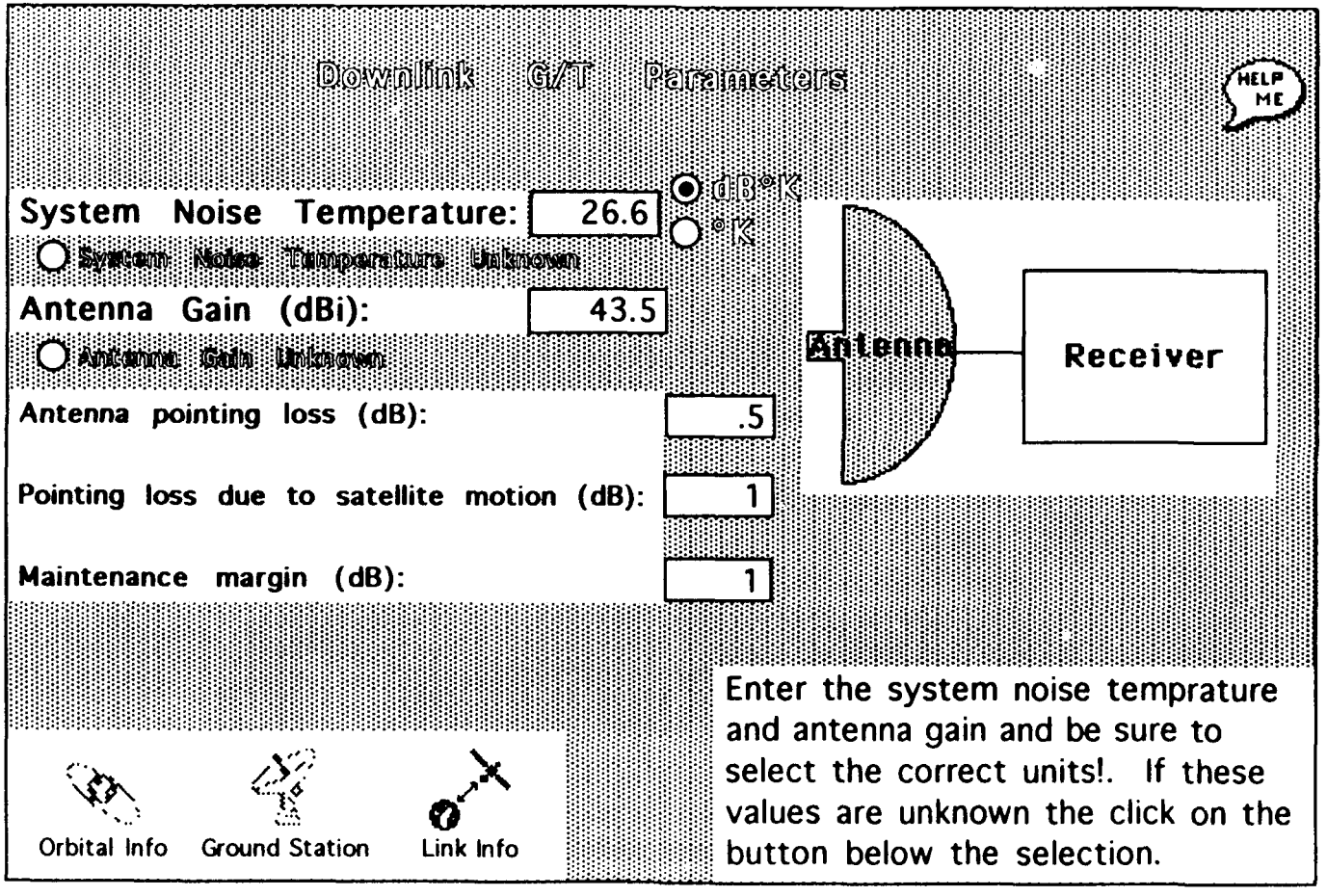

Link Frequencys & Access Type
HELP ME
Uplink Frequency (GHz): 14
Downlink Frequency (GHz): 12
Enter the uplink and downlink frequencies.
Orbital Info
Ground Station
Link Info

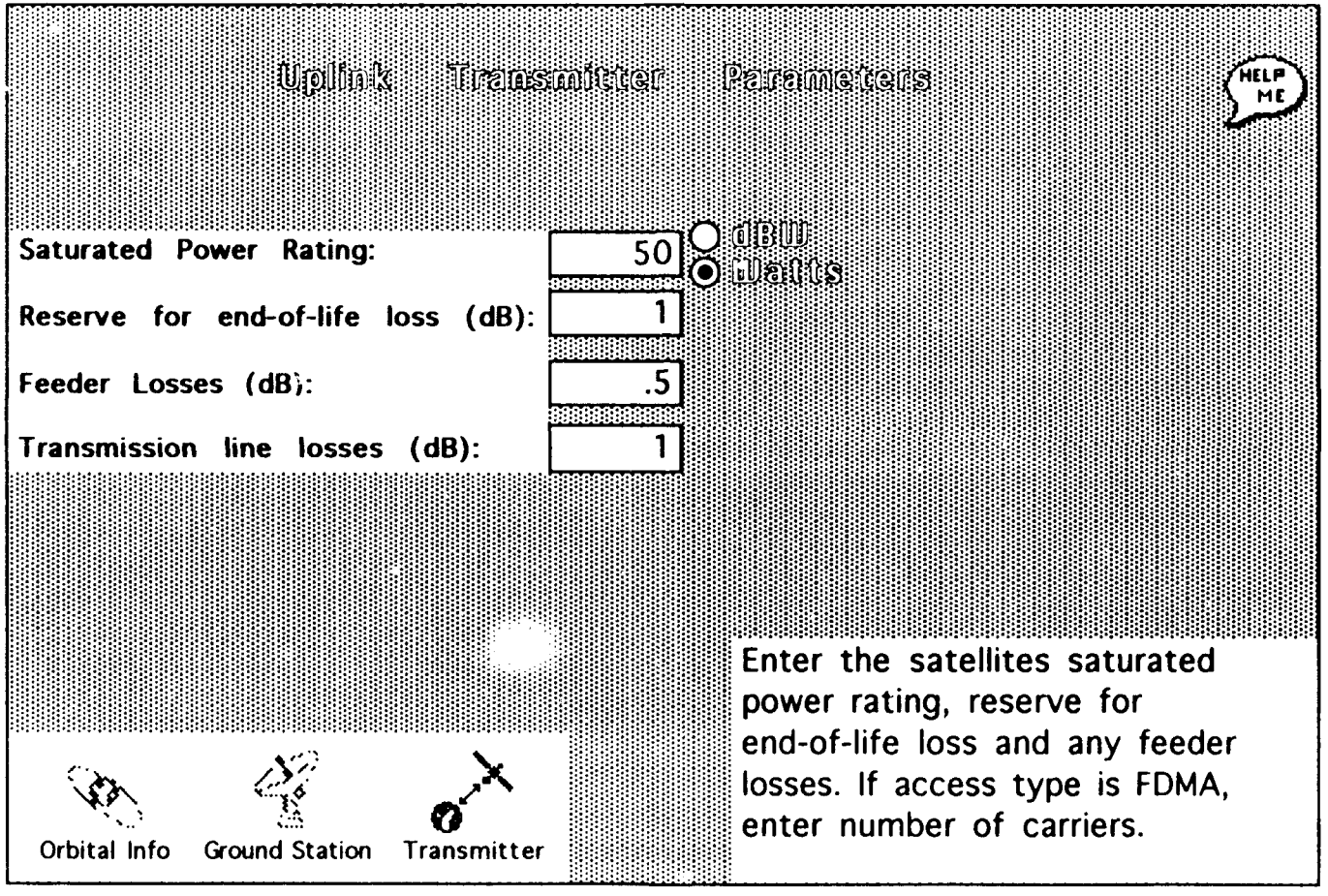

Jamming Losses
HELP ME
Jam Uplink Receiver
Jammer power at the antenna port (dBW):
-148.4
Jammer Power Unknown
Jam Downlink Receiver
Jammer power at the antenna port (dBW):
-148.7
Jammer Power Unknown
To include jamming losses, enter the approriate jamming power for the uplink and downlink. If the power is unknown then select 'Jammer Power Unknown' to find the jammer power
Noise Bandwidth
Print Card
Ideal Budget
Full Budget
Rain Losses
Jamming Losses
Xmit Losses

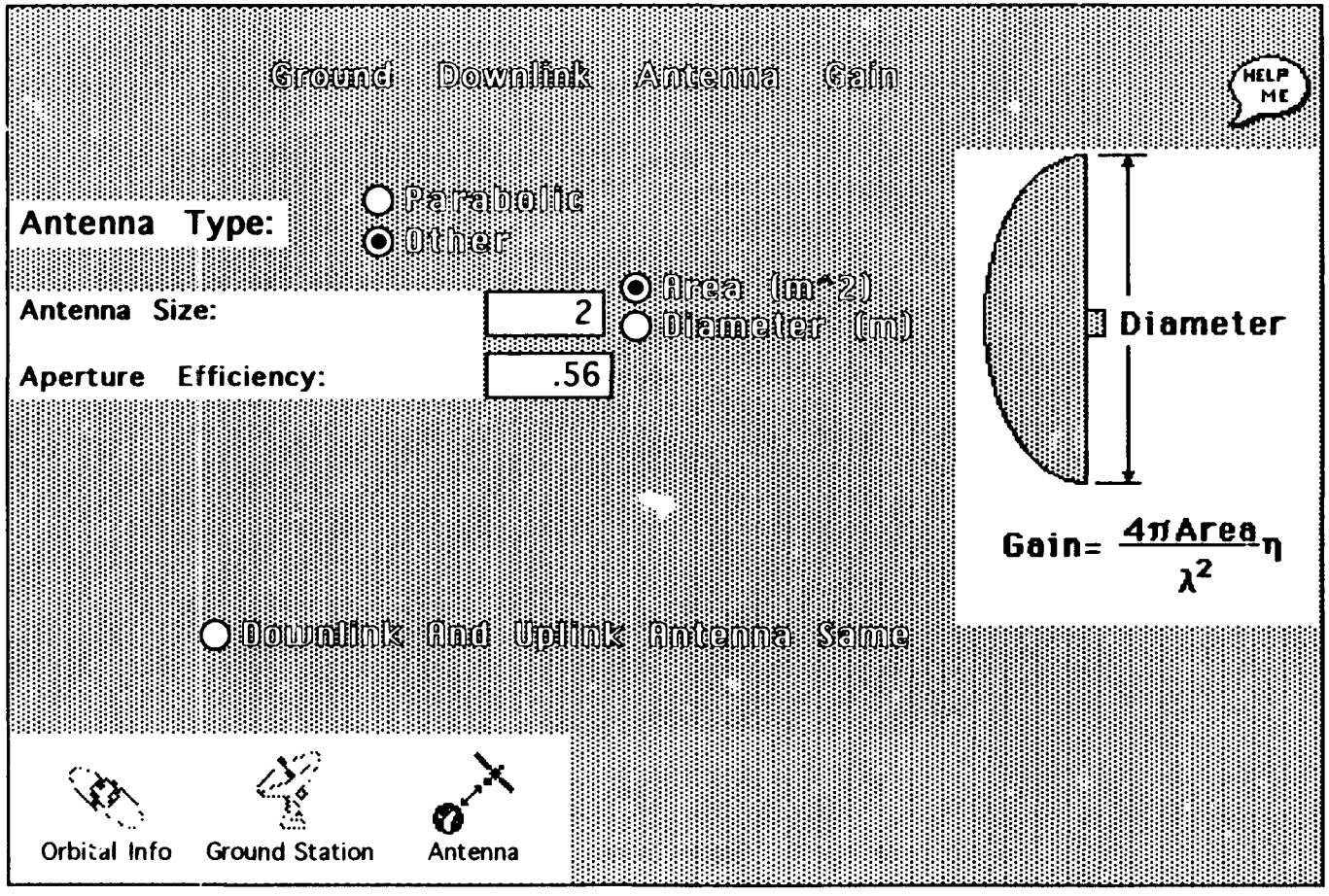

Transmission Losses
HELP ME
Include Transmission Losses
Uplink Losses
Atmospheric Losses (dB): 3
Propagation Losses (dB): .5
Downlink Losses
Atmospheric Losses (dB): 2
Propagation Losses (dB): .5
Enter the losses due to atmospheric constituents and the propagation losses due to scintillation and polarization coupling. To include these losses into the full link budget computations click on the 'Include Transmission Losses' button.
Noise Bandwidth
Print Card
Ideal Budget
Full Budget
Rain Losses
Jamming Losses
Xmit Losses

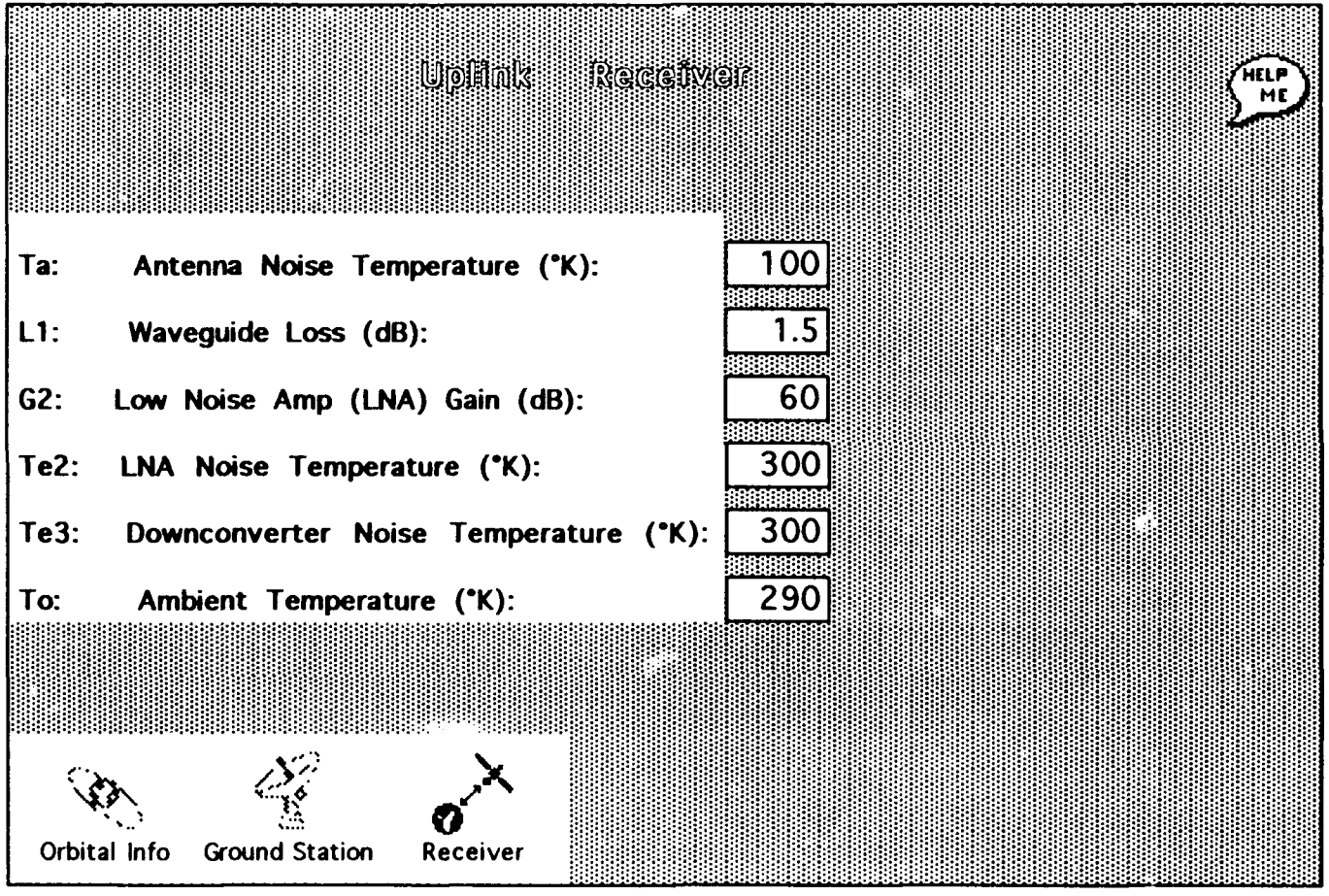

Rain Losses
HELP ME
Include Uplink Rain Losses
Include Downlink Rain Losses
Display Uplink Rain Rate
Display Downlink Rain Rate
Calculate Rain Losses
Rain Region:
Select the surface point rain rate:
P% (mm/Hr)
0.001
0.002
0.005
0.01
0.02
0.05
P% (mm/Hr)
0.1
0.2
0.5
1.0
2.0
5.0
To include rain losses, select a surface point rain rate and then calculate the rain loss. Then select 'Include Rain Losses' prior to leaving the card.
Noise Bandwidth
Print Card
Ideal Budget
Full Budget
Rain Losses
Jamming Losses
Xmit Losses

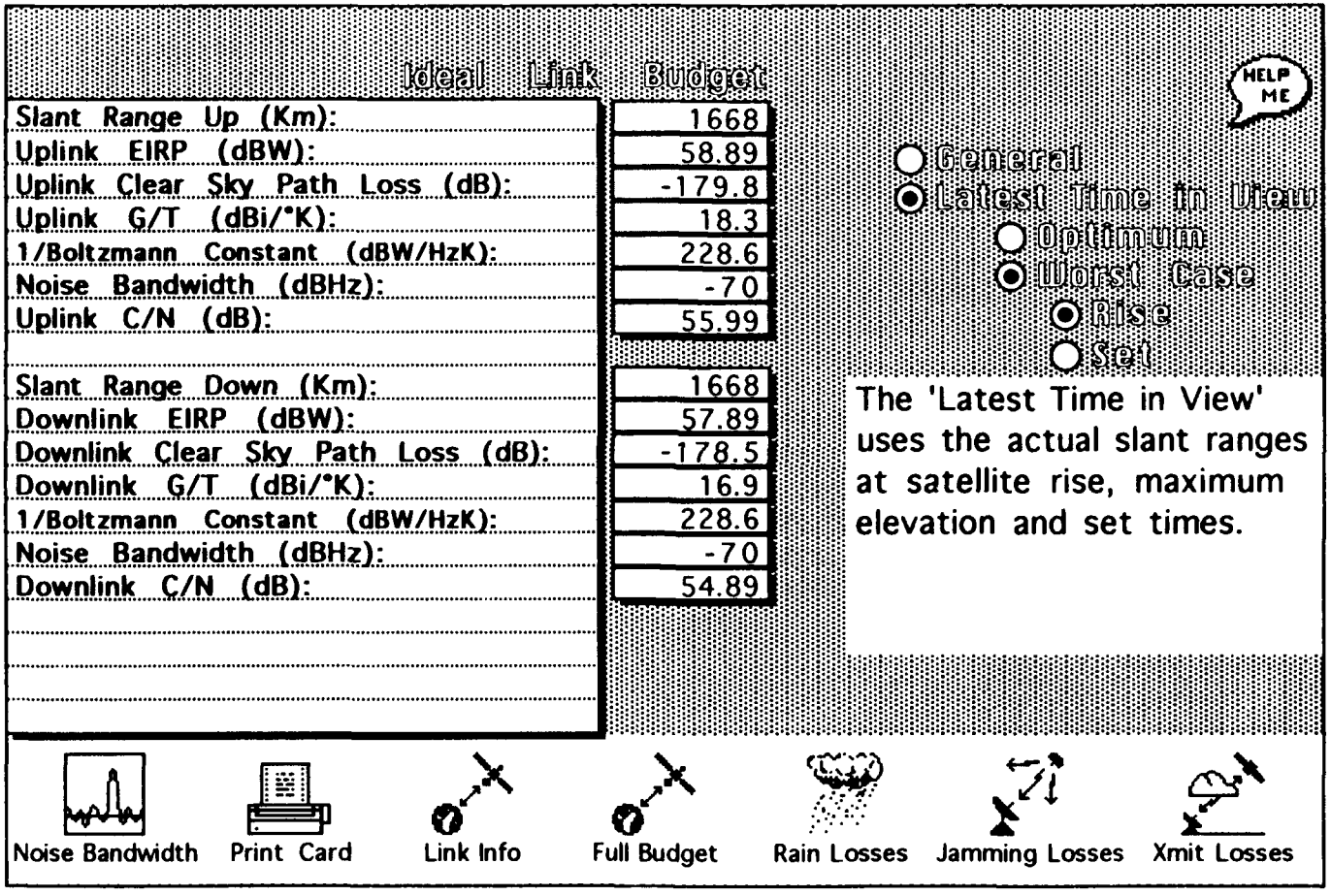

Downlink EIRP Parameters
HELP ME
Transmitter Power: 14.49
dBW
Watts
Transmitter Power Unknown
Antenna Gain (dBi): 44.9
Antenna Gain Unknown
Satellite Transmitter Output Backoff (dB): .5
Satellite Transmitter Input Backoff (dB): 1
Transmitter
Antenna
Orbital Info
Ground Station
Link Info
Enter the transmitter power and antenna gain and be sure to select the correct units!. If these values are unknown the click on the button below the selection.

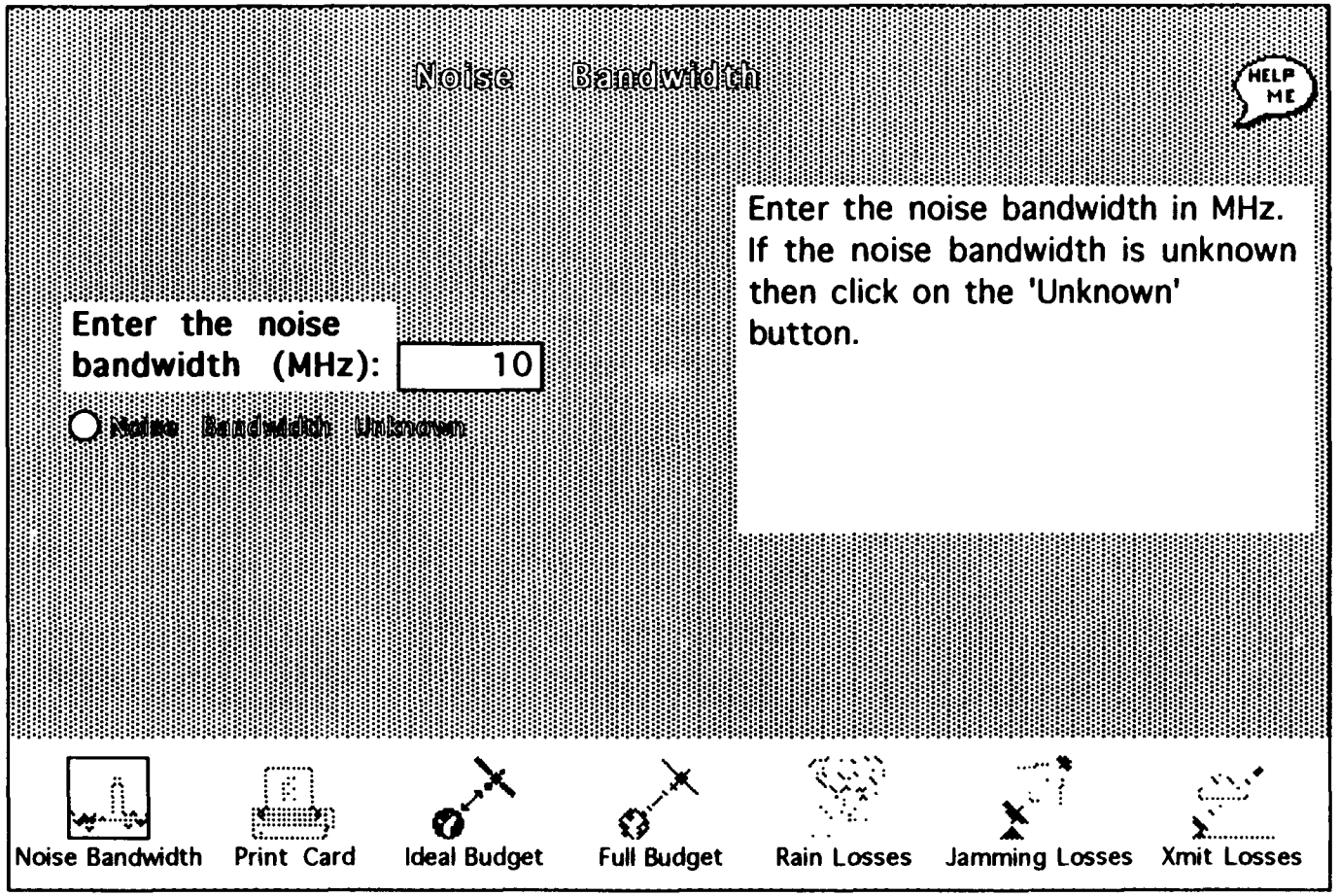

Downlink G/T Parameters
HELP ME
System Noise Temperature:
26.6
dB°K
°K
System Noise Temperature Unknown
Antenna Gain (dBi):
43.5
Antenna Gain Unknown
Antenna pointing loss (dB):
.5
Pointing loss due to satellite motion (dB):
1
Maintenance margin (dB):
1
Antenna
Receiver
Orbital Info
Ground Station
Link Info
Enter the system noise temprature and antenna gain and be sure to select the correct units!. If these values are unknown the click on the button below the selection.

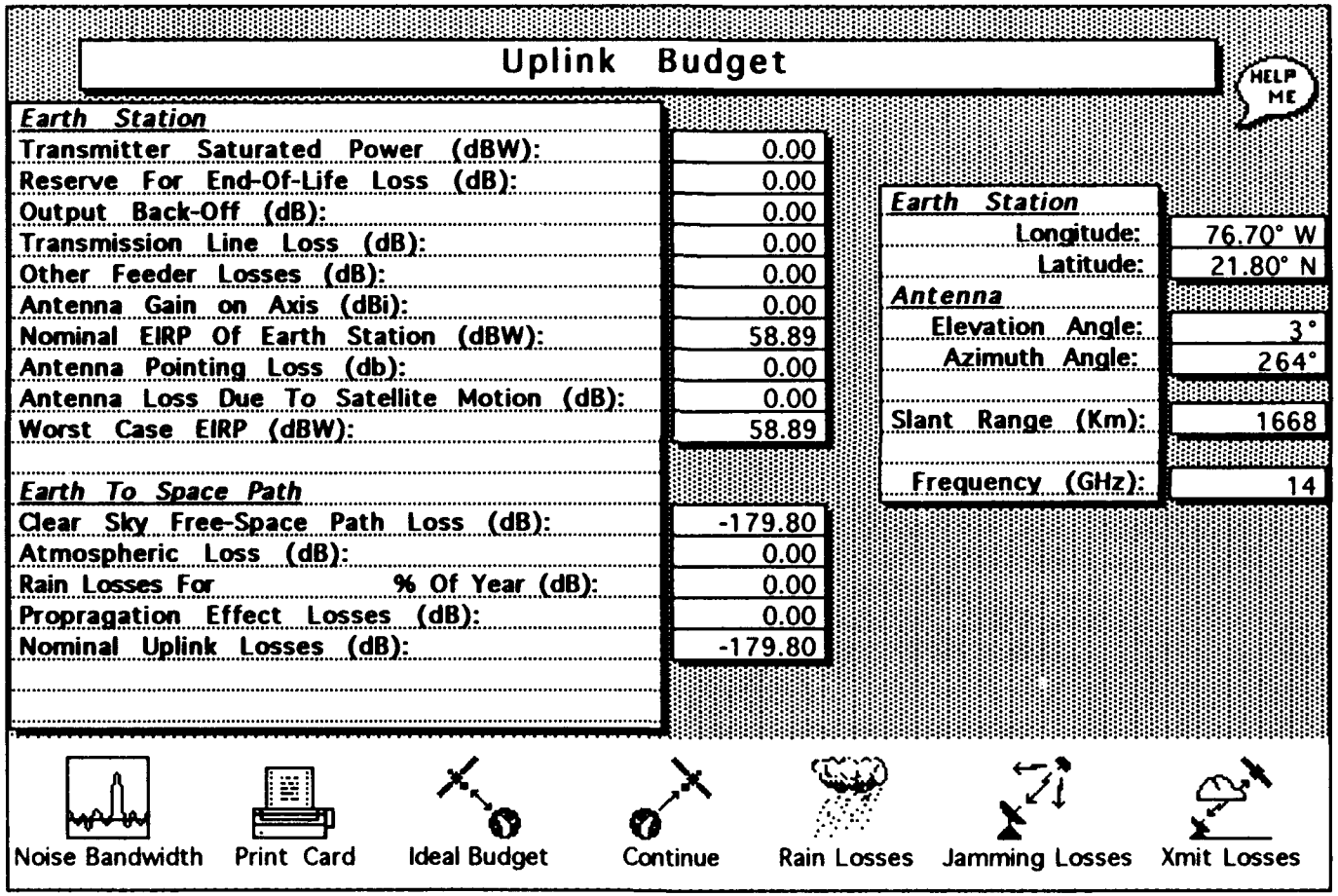

Uplink Transmitter Parameters
HELP ME
Saturated Power Rating:
50
dBW
Watts
Reserve for end-of-life loss (dB):
1
Feeder Losses (dB):
.5
Transmission line losses (dB):
1
Orbital Info
Ground Station
Transmitter
Enter the satellites saturated power rating, reserve for end-of-life loss and any feeder losses. If access type is FDMA, enter number of carriers.

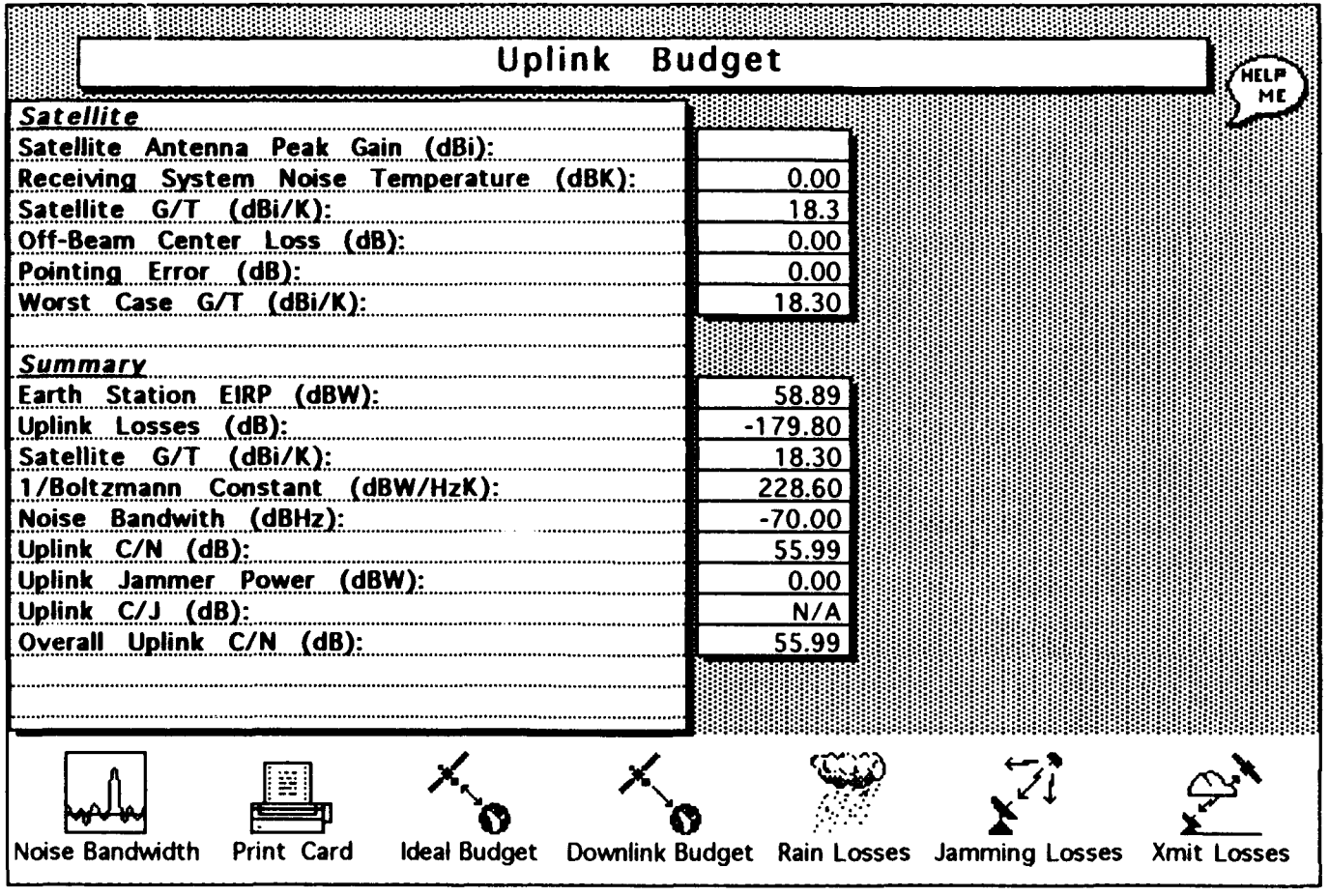

Ground Downlink Antenna Gain
HELP ME
Antenna Type:
Parabolic
Other
Antenna Size:
2
Area (m^2)
Diameter (m)
Aperture Efficiency:
.56
Diameter
Gain= 4πArea/λ^2 η
Downlink And Uplink Antenna Same
Orbital Info
Ground Station
Antenna

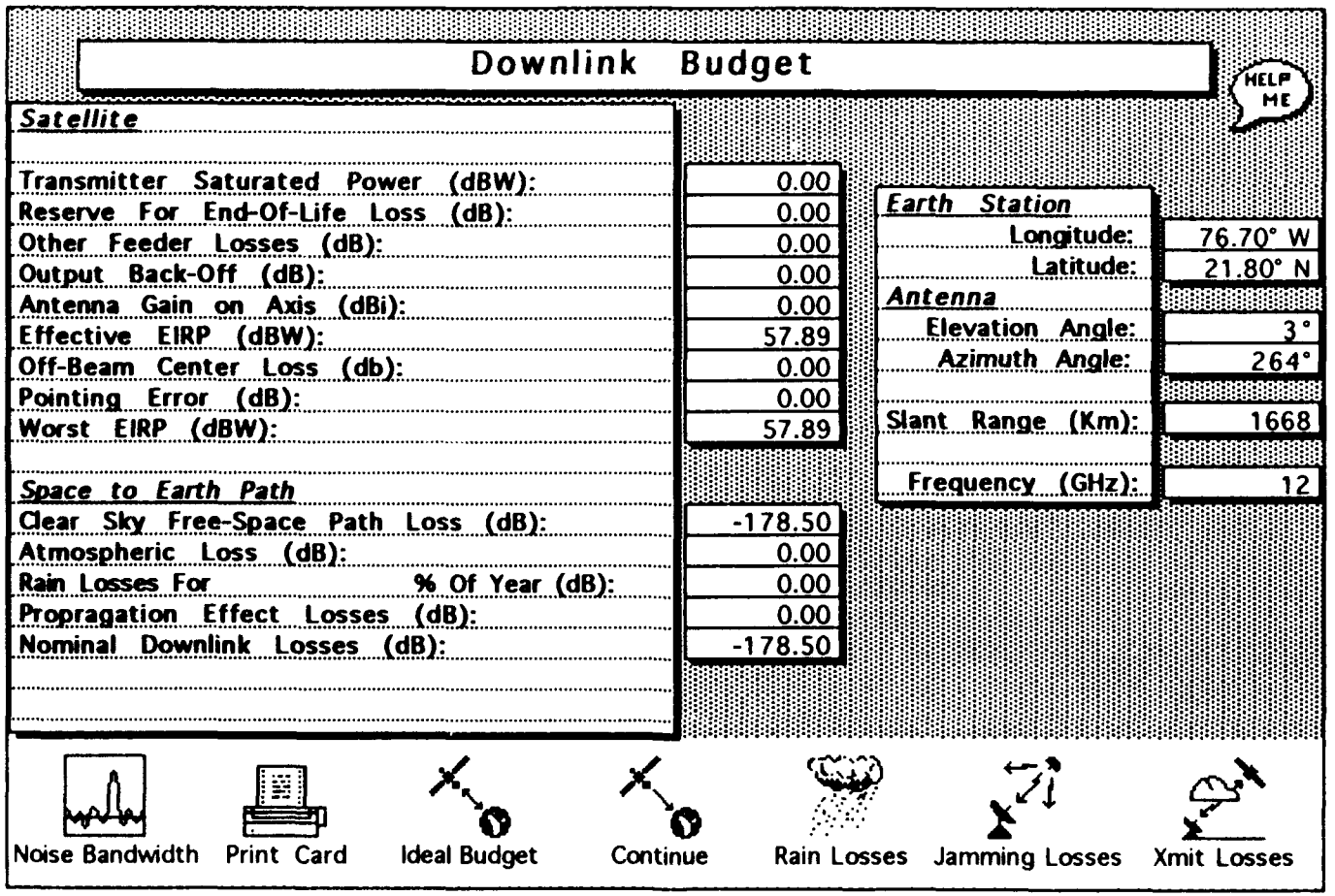

UpLink Receiver
HELP ME
Ta: Antenna Noise Temperature (°K): 100
L1: Waveguide Loss (dB): 1.5
G2: Low Noise Amp (LNA) Gain (dB): 60
Te2: LNA Noise Temperature (°K): 300
Te3: Downconverter Noise Temperature (°K): 300
To: Ambient Temperature (°K): 290
Orbital Info
Ground Station
Receiver

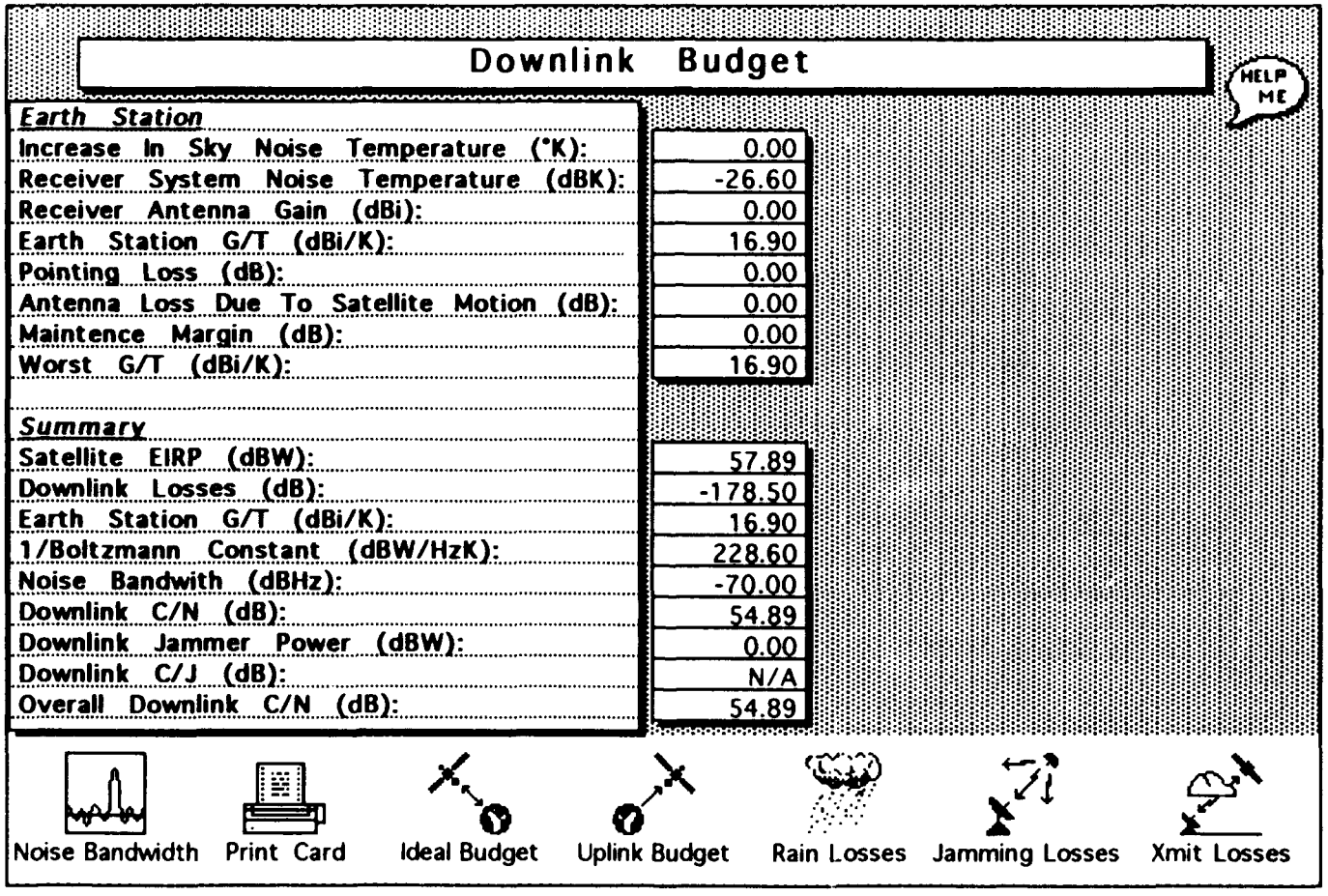

Ideal Link Budget
HELP ME
Slant Range Up (Km): 1668
Uplink EIRP (dBW): 58.89
Uplink Clear Sky Path Loss (dB): -179.8
Uplink G/T (dBi/°K): 18.3
1/Boltzmann Constant (dBW/HzK): 228.6
Noise Bandwidth (dBHz): -70
Uplink C/N (dB): 55.99
Slant Range Down (Km): 1668
Downlink EIRP (dBW): 57.89
Downlink Clear Sky Path Loss (dB): -178.5
Downlink G/T (dBi/°K): 16.9
1/Boltzmann Constant (dBW/HzK): 228.6
Noise Bandwidth (dBHz): -70
Downlink C/N (dB): 54.89
General
Latest Time in View
Optimum
Worst Case
Rise
Set
The 'Latest Time in View' uses the actual slant ranges at satellite rise, maximum elevation and set times.
Noise Bandwidth
Print Card
Link Info
Full Budget
Rain Losses
Jamming Losses
Xmit Losses

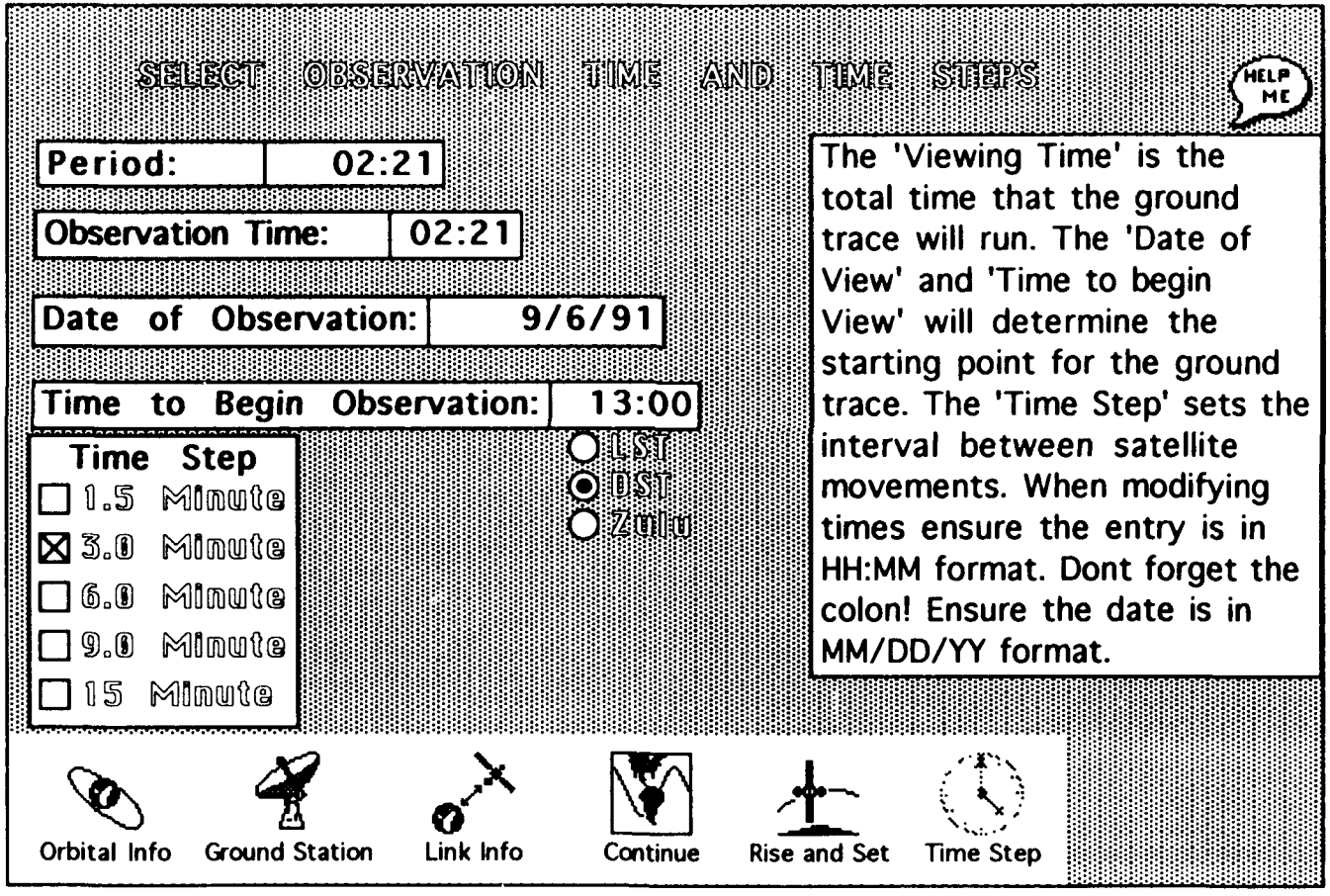

Noise Bandwidth
HELP ME
Enter the noise bandwidth in MHz. If the noise bandwidth is unknown then click on the 'Unknown' button.
Enter the noise bandwidth (MHz):
10
Noise Bandwidth Unknown
Noise Bandwidth
Print Card
Ideal Budget
Full Budget
Rain Losses
Jamming Losses
Xmit Losses

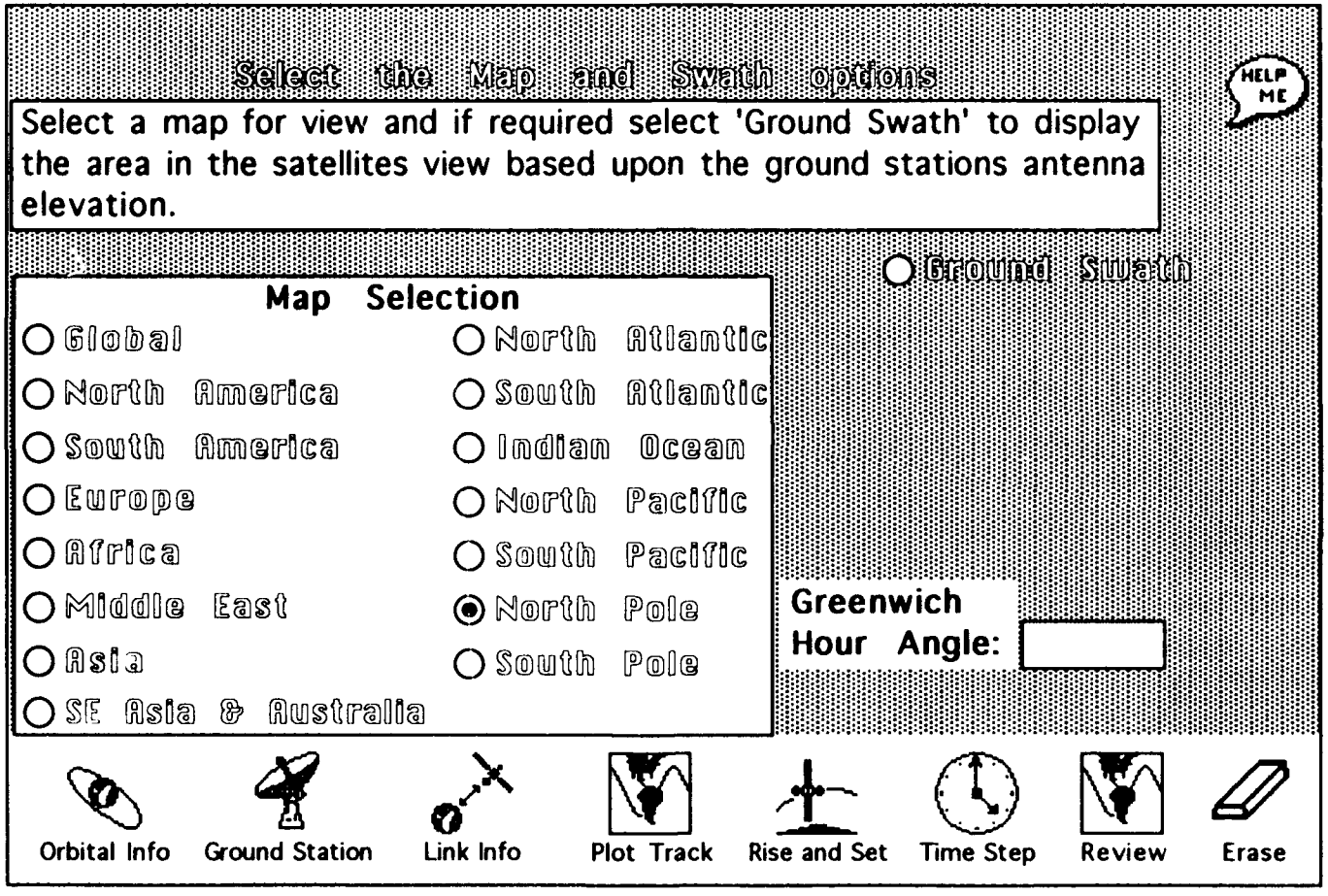

Uplink Budget
HELP ME
Earth Station
Transmitter Saturated Power (dBW): 0.00
Reserve For End-Of-Life Loss (dB): 0.00
Output Back-Off (dB): 0.00
Transmission Line Loss (dB): 0.00
Other Feeder Losses (dB): 0.00
Antenna Gain on Axis (dBi): 0.00
Nominal EIRP Of Earth Station (dBW): 58.89
Antenna Pointing Loss (db): 0.00
Antenna Loss Due To Satellite Motion (dB): 0.00
Worst Case EIRP (dBW): 58.89
Earth To Space Path
Clear Sky Free-Space Path Loss (dB): -179.80
Atmospheric Loss (dB): 0.00
Rain Losses For % Of Year (dB): 0.00
Propragation Effect Losses (dB): 0.00
Nominal Uplink Losses (dB): -179.80
Earth Station
Longitude: 76.70° W
Latitude: 21.80° N
Antenna
Elevation Angle: 3°
Azimuth Angle: 264°
Slant Range (Km): 1668
Frequency (GHz): 14
Noise Bandwidth
Print Card
Ideal Budget
Continue
Rain Losses
Jamming Losses
Xmit Losses

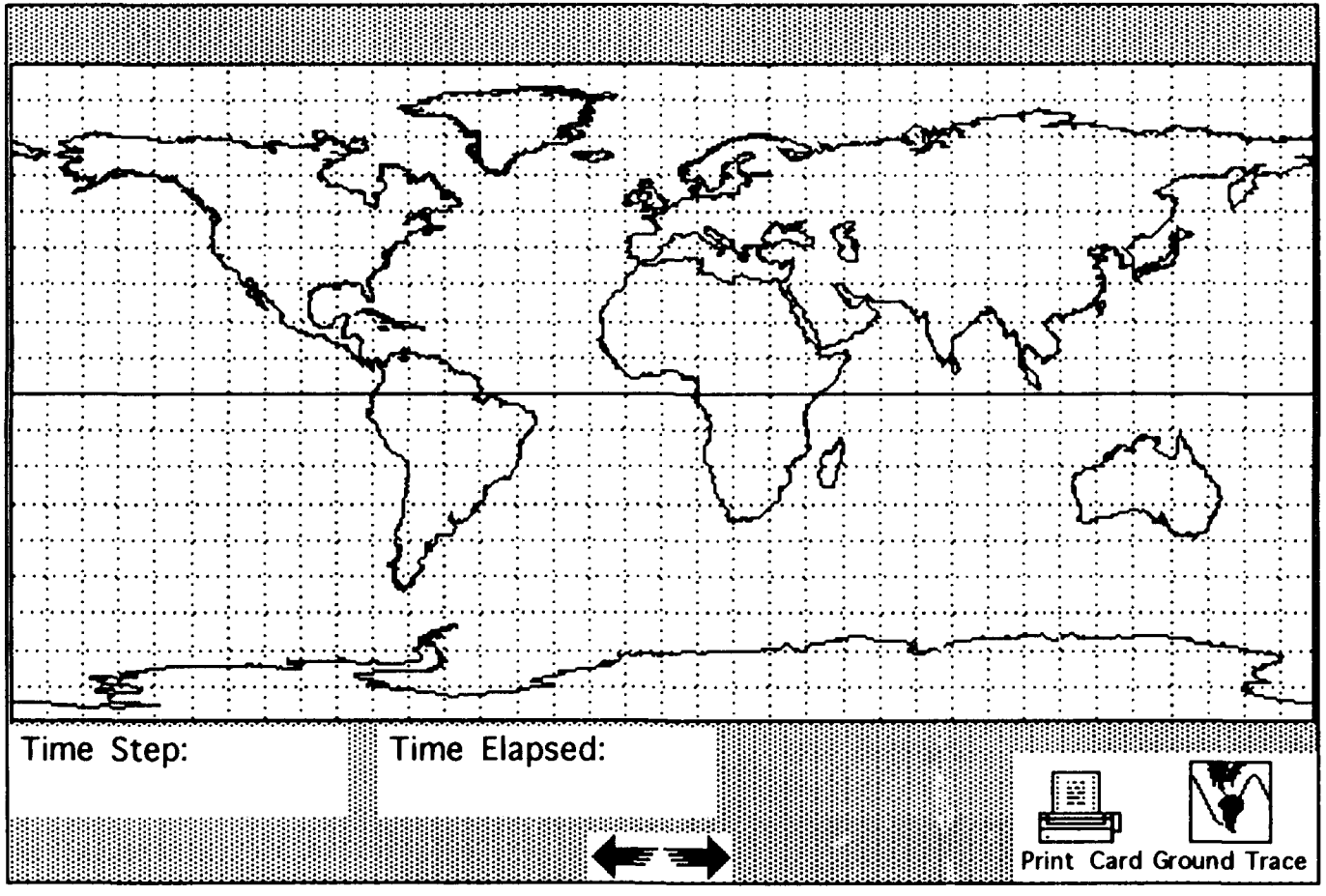

Uplink Budget
HELP ME
Satellite
Satellite Antenna Peak Gain (dBi):
Receiving System Noise Temperature (dBK): 0.00
Satellite G/T (dBi/K): 18.3
Off-Beam Center Loss (dB): 0.00
Pointing Error (dB): 0.00
Worst Case G/T (dBi/K): 18.30
Summary
Earth Station EIRP (dBW): 58.89
Uplink Losses (dB): -179.80
Satellite G/T (dBi/K): 18.30
1/Boltzmann Constant (dBW/HzK): 228.60
Noise Bandwith (dBHz): -70.00
Uplink C/N (dB): 55.99
Uplink Jammer Power (dBW): 0.00
Uplink C/J (dB): N/A
Overall Uplink C/N (dB): 55.99
Noise Bandwidth
Print Card
Ideal Budget
Downlink Budget
Rain Losses
Jamming Losses
Xmit Losses

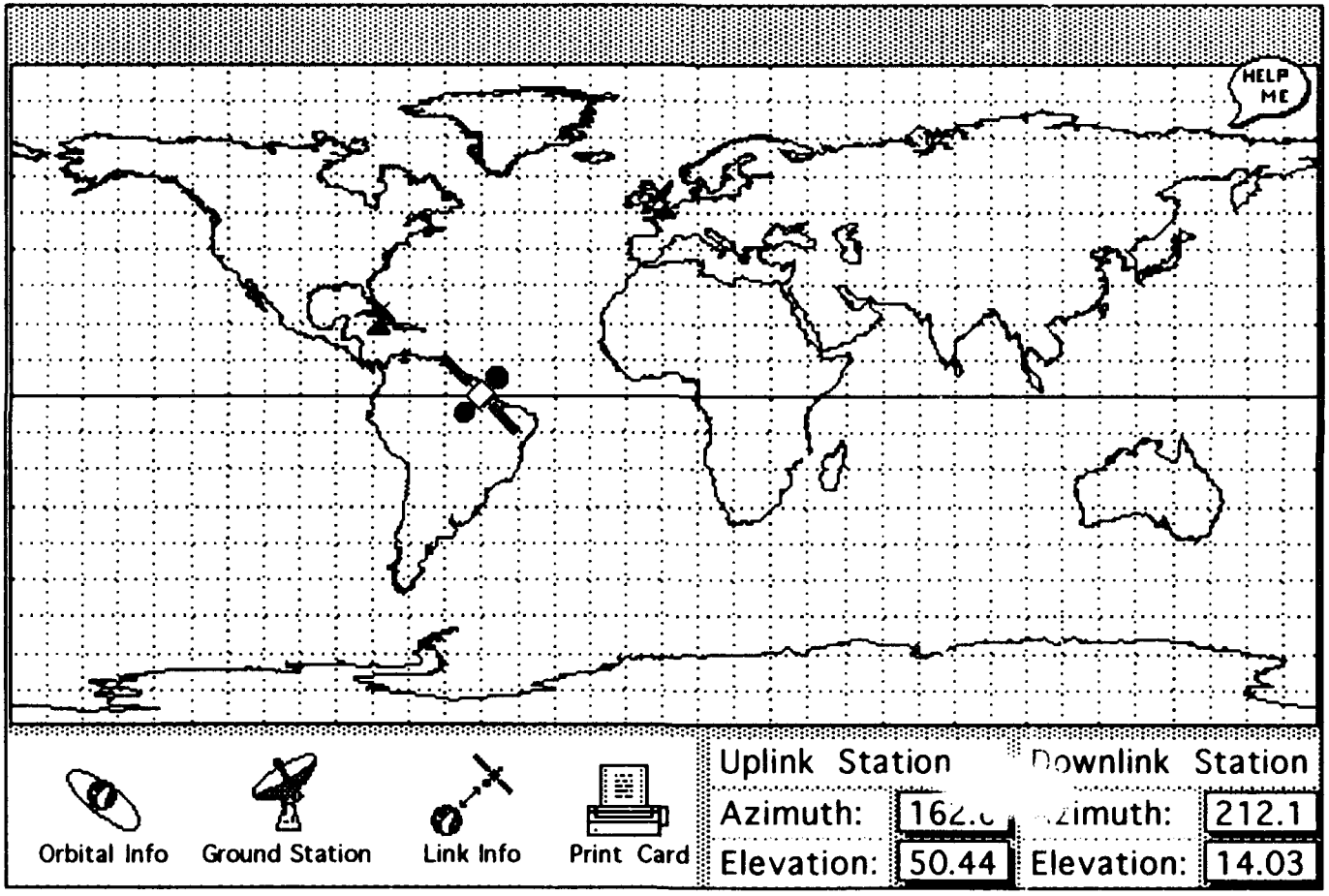

Downlink Budget
HELP ME
Satellite
Transmitter Saturated Power (dBW): 0.00
Reserve For End-Of-Life Loss (dB): 0.00
Other Feeder Losses (dB): 0.00
Output Back-Off (dB): 0.00
Antenna Gain on Axis (dBi): 0.00
Effective EIRP (dBW): 57.89
Off-Beam Center Loss (db): 0.00
Pointing Error (dB): 0.00
Worst EIRP (dBW): 57.89
Space to Earth Path
Clear Sky Free-Space Path Loss (dB): -178.50
Atmospheric Loss (dB): 0.00
Rain Losses For % Of Year (dB): 0.00
Propragation Effect Losses (dB): 0.00
Nominal Downlink Losses (dB): -178.50
Earth Station
Longitude: 76.70° W
Latitude: 21.80° N
Antenna
Elevation Angle: 3°
Azimuth Angle: 264°
Slant Range (Km): 1668
Frequency (GHz): 12
Noise Bandwidth
Print Card
Ideal Budget
Continue
Rain Losses
Jamming Losses
Xmit Losses

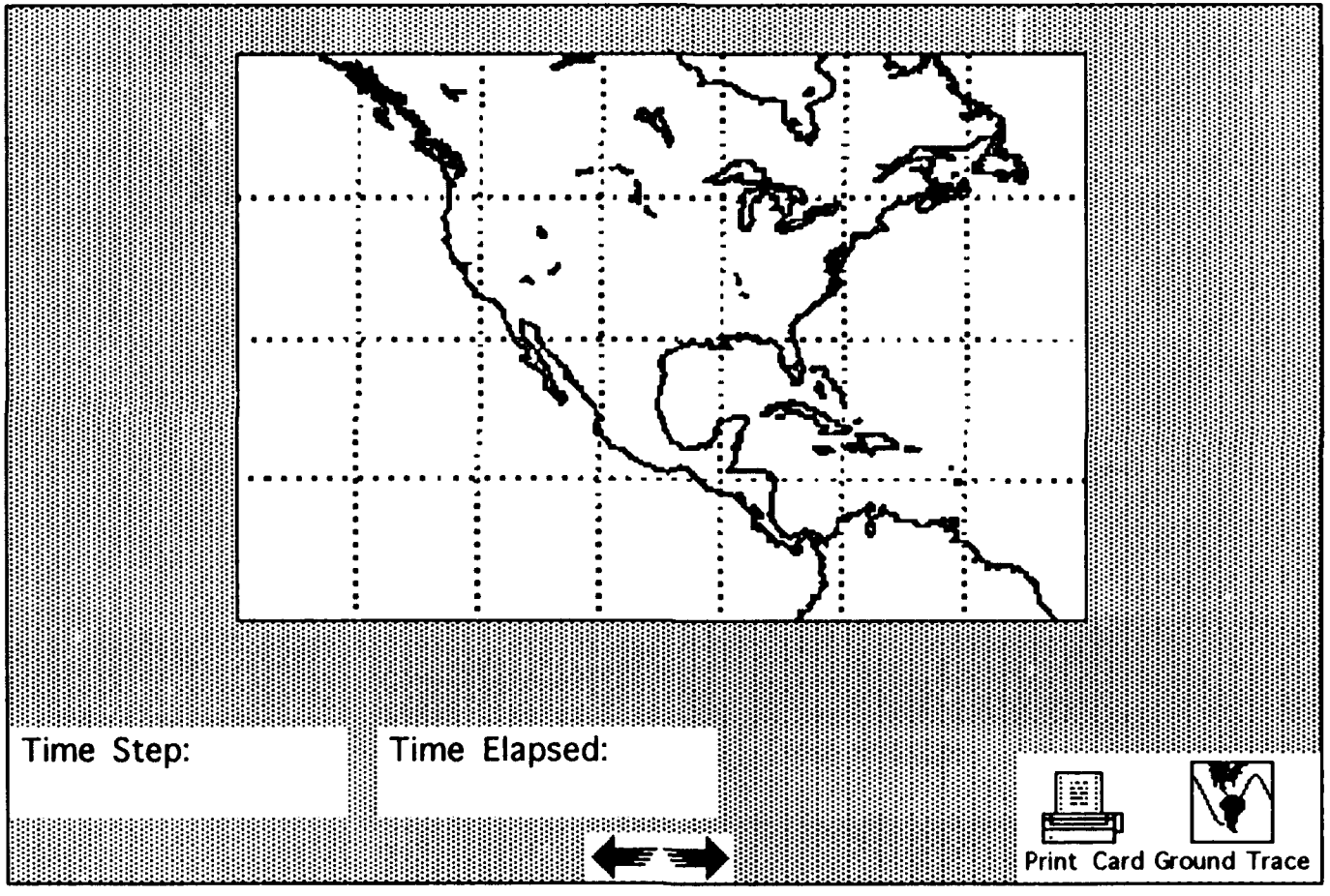

Downlink Budget
HELP ME
Earth Station
Increase In Sky Noise Temperature (°K): 0.00
Receiver System Noise Temperature (dBK): -26.60
Receiver Antenna Gain (dBi): 0.00
Earth Station G/T (dBi/K): 16.90
Pointing Loss (dB): 0.00
Antenna Loss Due To Satellite Motion (dB): 0.00
Maintence Margin (dB): 0.00
Worst G/T (dBi/K): 16.90
Summary
Satellite EIRP (dBW): 57.89
Downlink Losses (dB): -178.50
Earth Station G/T (dBi/K): 16.90
1/Boltzmann Constant (dBW/HzK): 228.60
Noise Bandwith (dBHz): -70.00
Downlink C/N (dB): 54.89
Downlink Jammer Power (dBW): 0.00
Downlink C/J (dB): N/A
Overall Downlink C/N (dB): 54.89
Noise Bandwidth
Print Card
Ideal Budget
Uplink Budget
Rain Losses
Jamming Losses
Xmit Losses

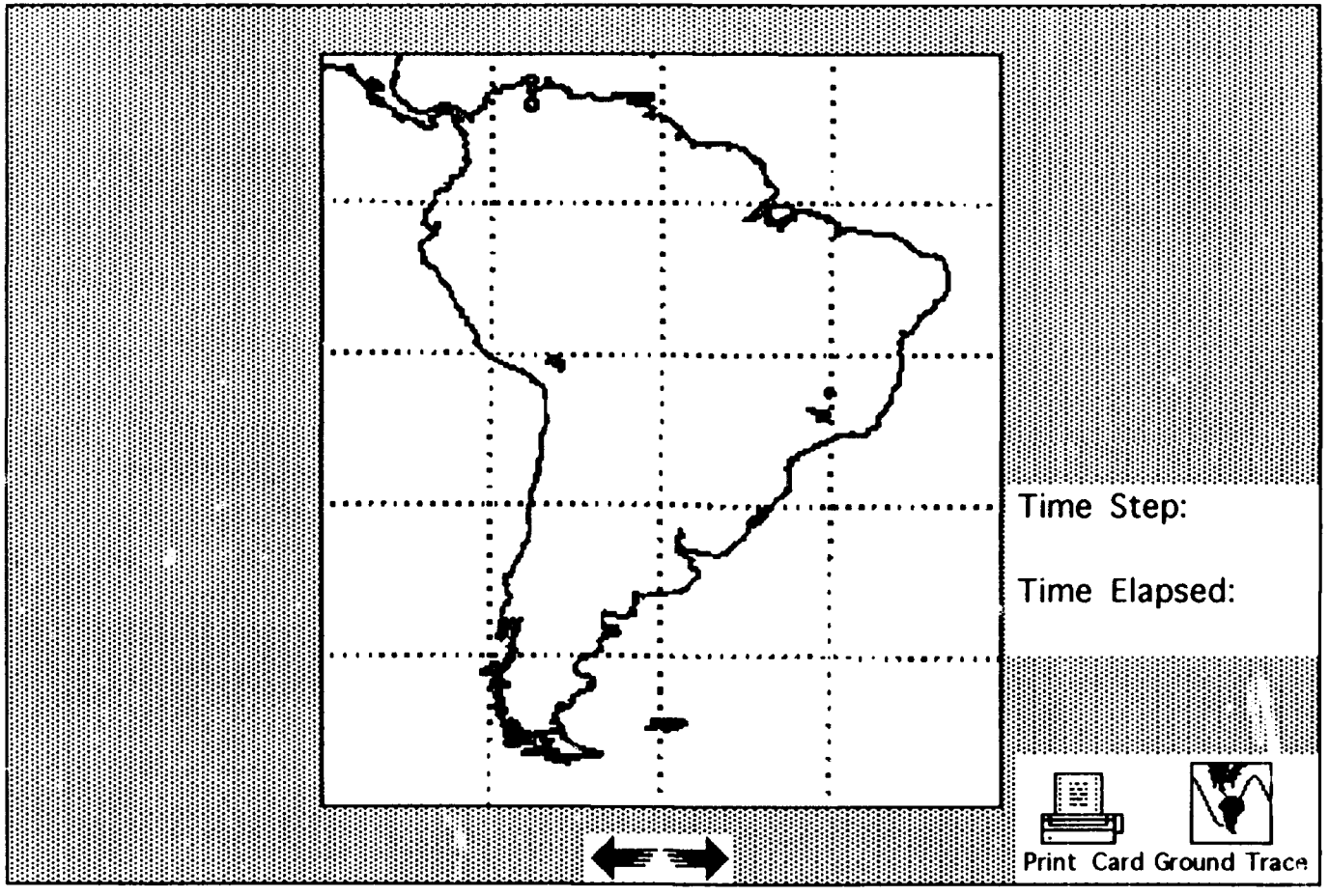

SELECT OBSERVATION TIME AND TIME STEPS
HELP ME
Period: 02:21
Observation Time: 02:21
Date of Observation: 9/6/91
Time to Begin Observation: 13:00
LST
DST
Zulu
Time Step
1.5 Minute
3.0 Minute
6.0 Minute
9.0 Minute
15 Minute
The 'Viewing Time' is the total time that the ground trace will run. The 'Date of View' and 'Time to begin View' will determine the starting point for the ground trace. The 'Time Step' sets the interval between satellite movements. When modifying times ensure the entry is in HH:MM format. Dont forget the colon! Ensure the date is in MM/DD/YY format.
Orbital Info
Ground Station
Link Info
Continue
Rise and Set
Time Step

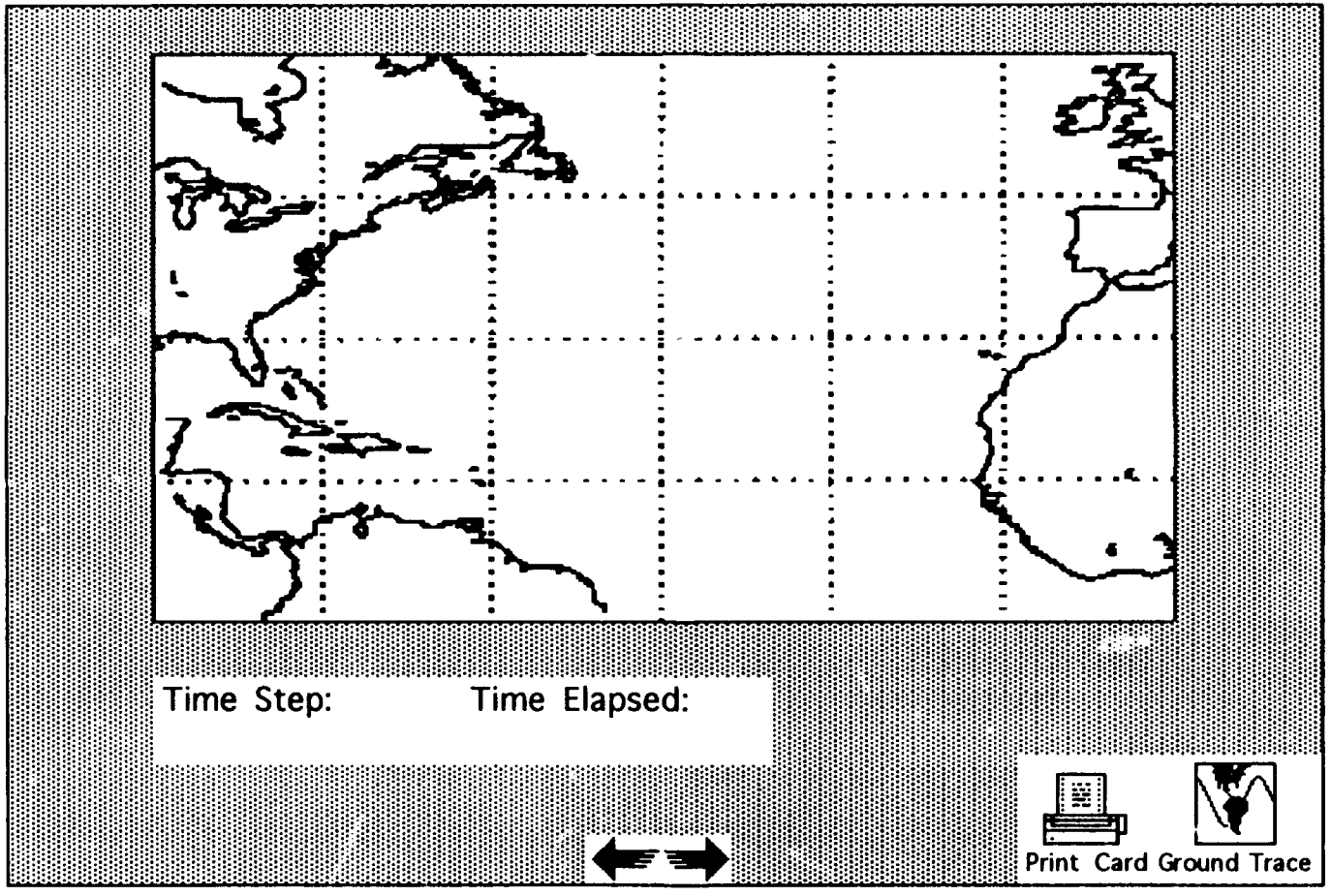

Select the Map and Swath options
HELP ME
Select a map for view and if required select 'Ground Swath' to display the area in the satellites view based upon the ground stations antenna elevation.
Ground Swath
Map Selection
Global
North America
South America
Europe
Africa
Middle East
Asia
SE Asia & Australia
North Atlantic
South Atlantic
Indian Ocean
North Pacific
South Pacific
North Pole
South Pole
Greenwich Hour Angle:
Orbital Info
Ground Station
Link Info
Plot Track
Rise and Set
Time Step
Review
Erase

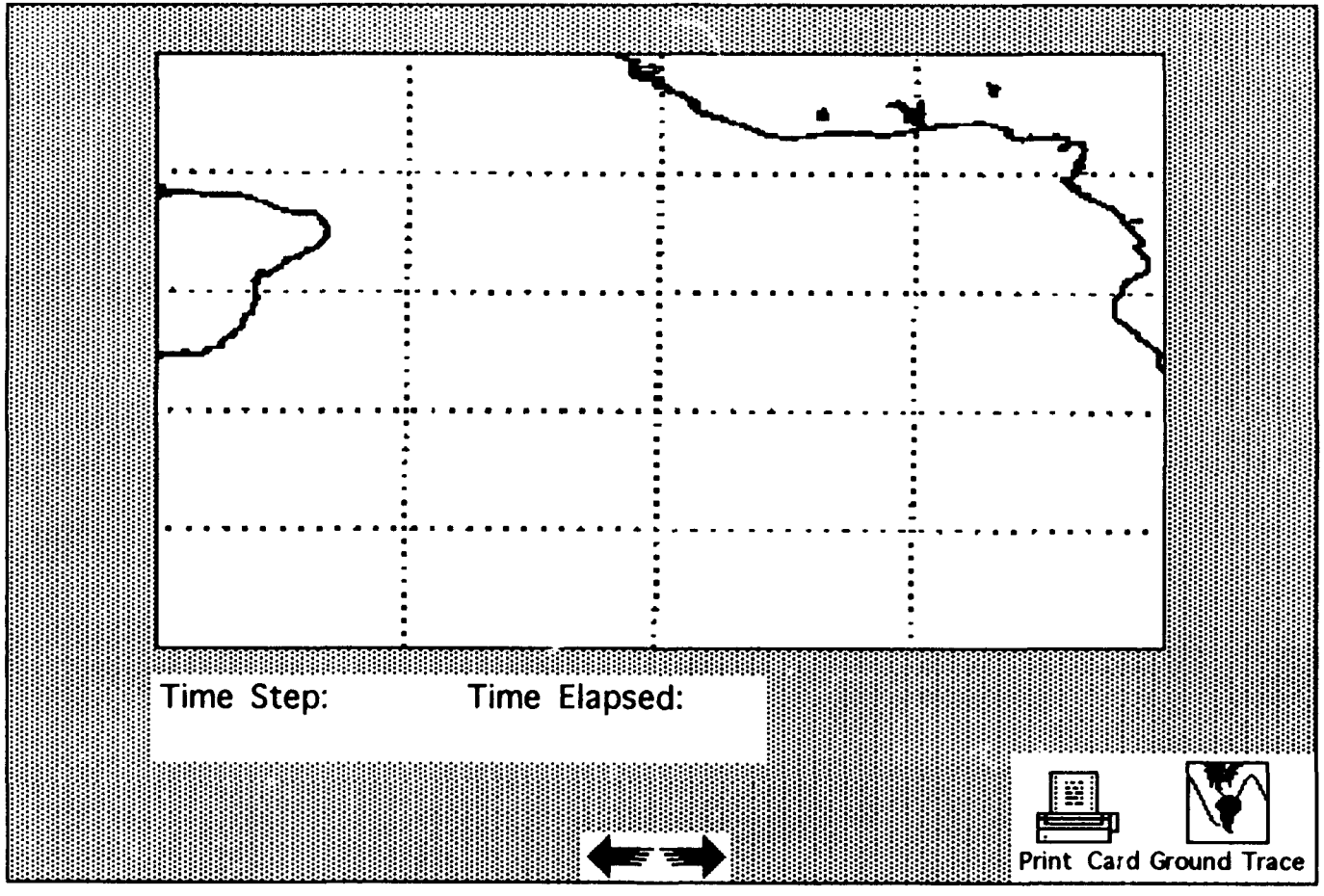

Time Step:
Time Elapsed:
Print
Card
Ground Trace

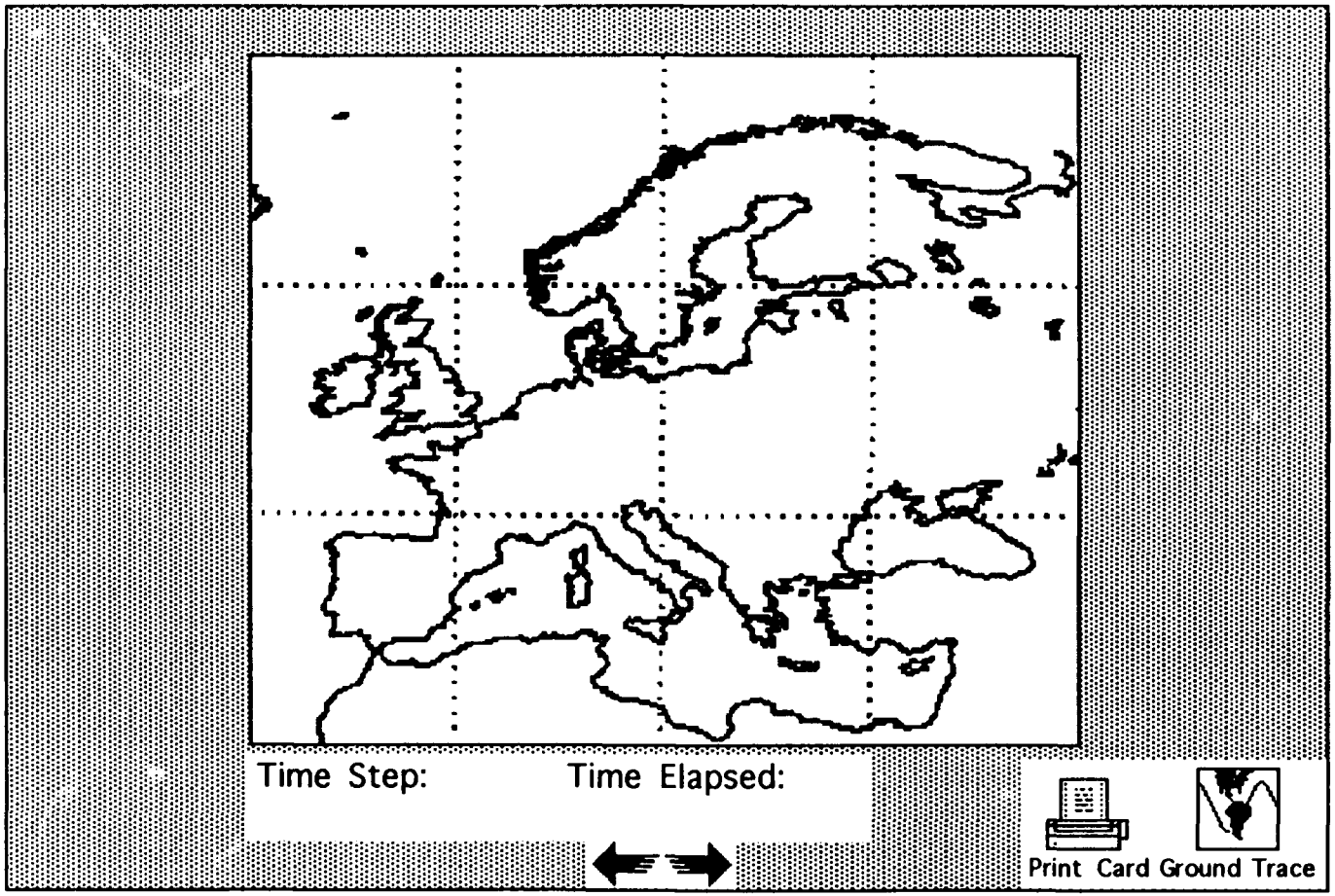

HELP ME
Orbital Info
Ground Station
Link Info
Print Card
Uplink Station
Azimuth:
Elevation: 50.44
Downlink Station
Azimuth: 212.1
Elevation: 14.03

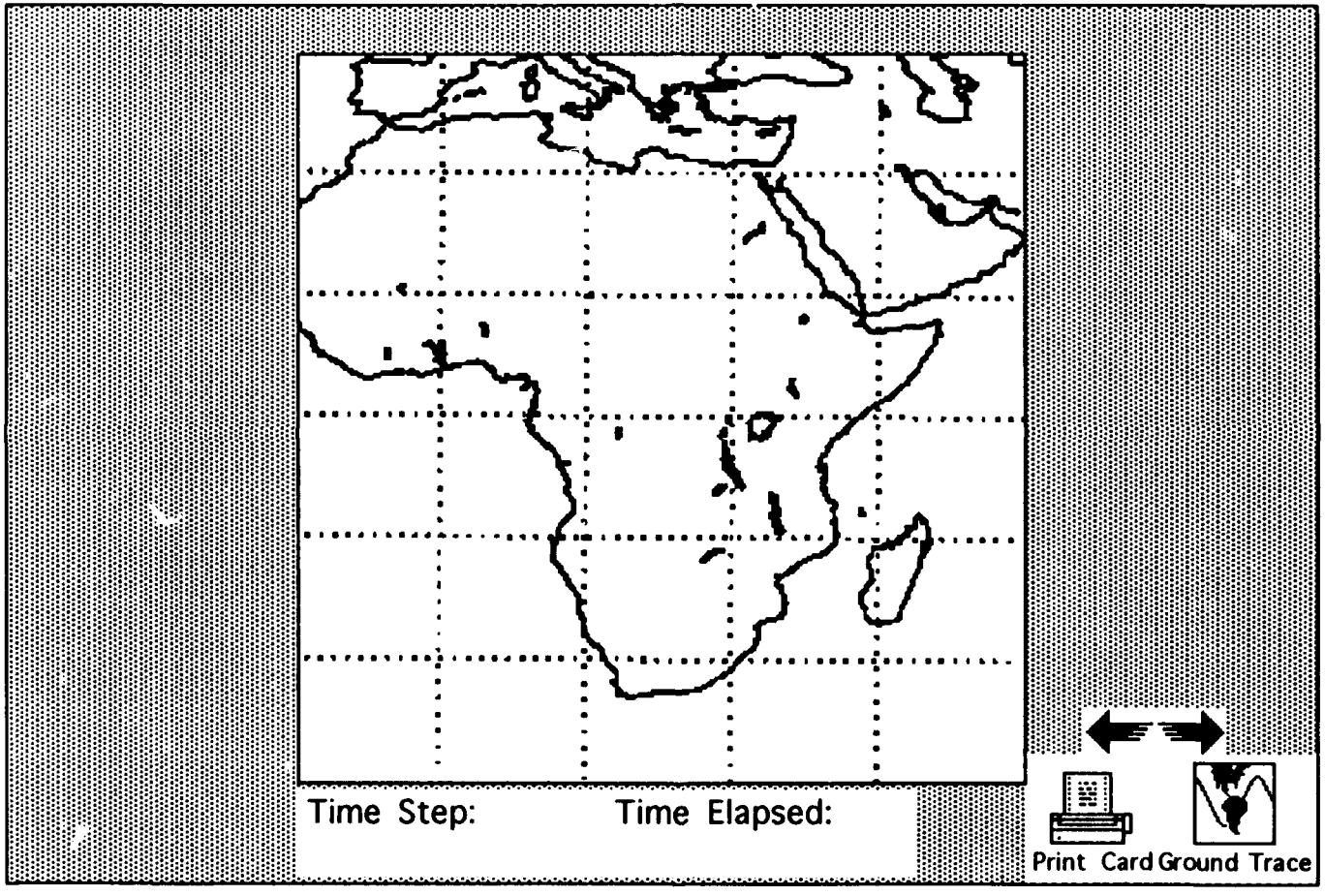

Time Step:
Time Elapsed:
Print Card
Ground Trace

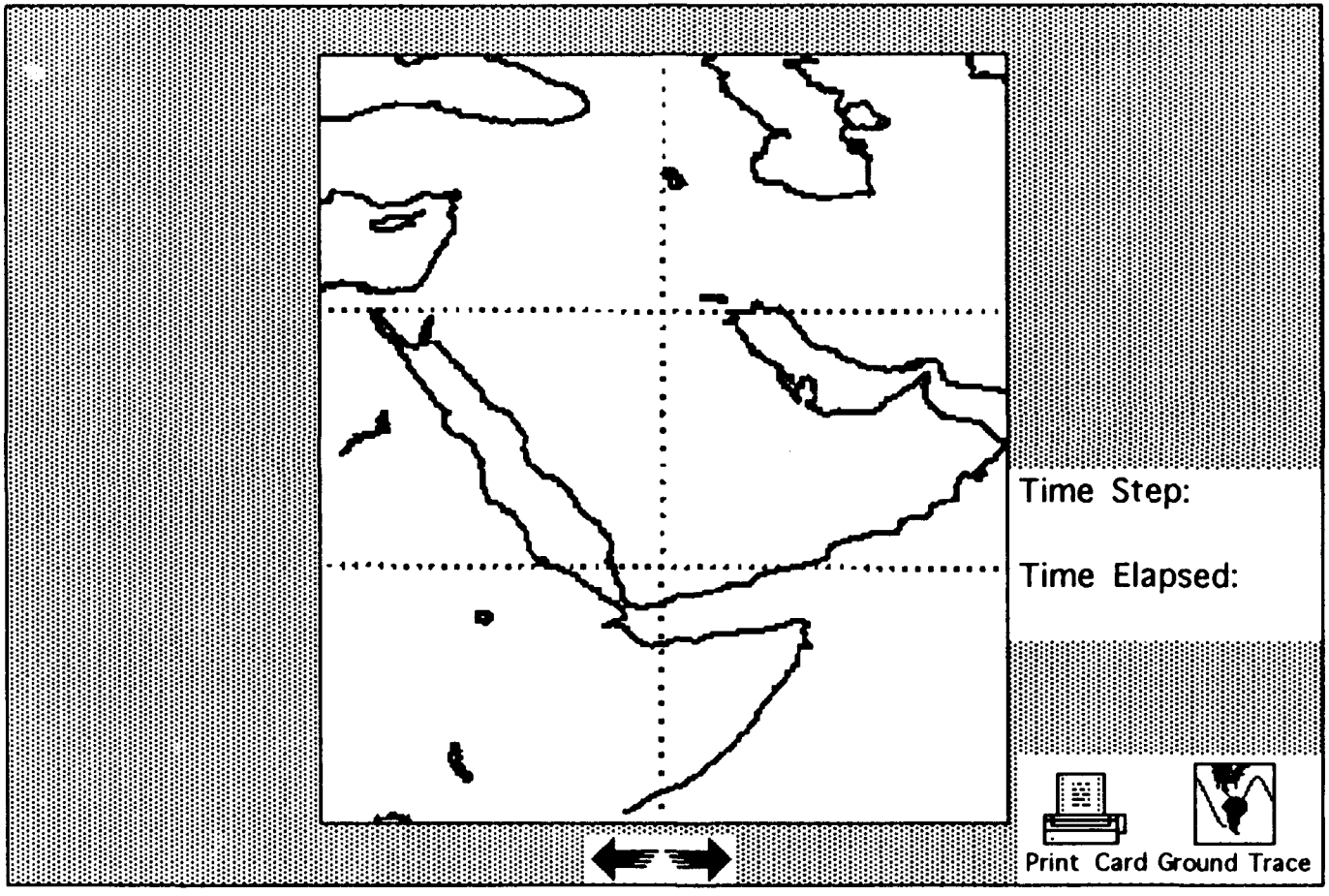

Time Step:
Time Elapsed:
Print Card
Ground Trace

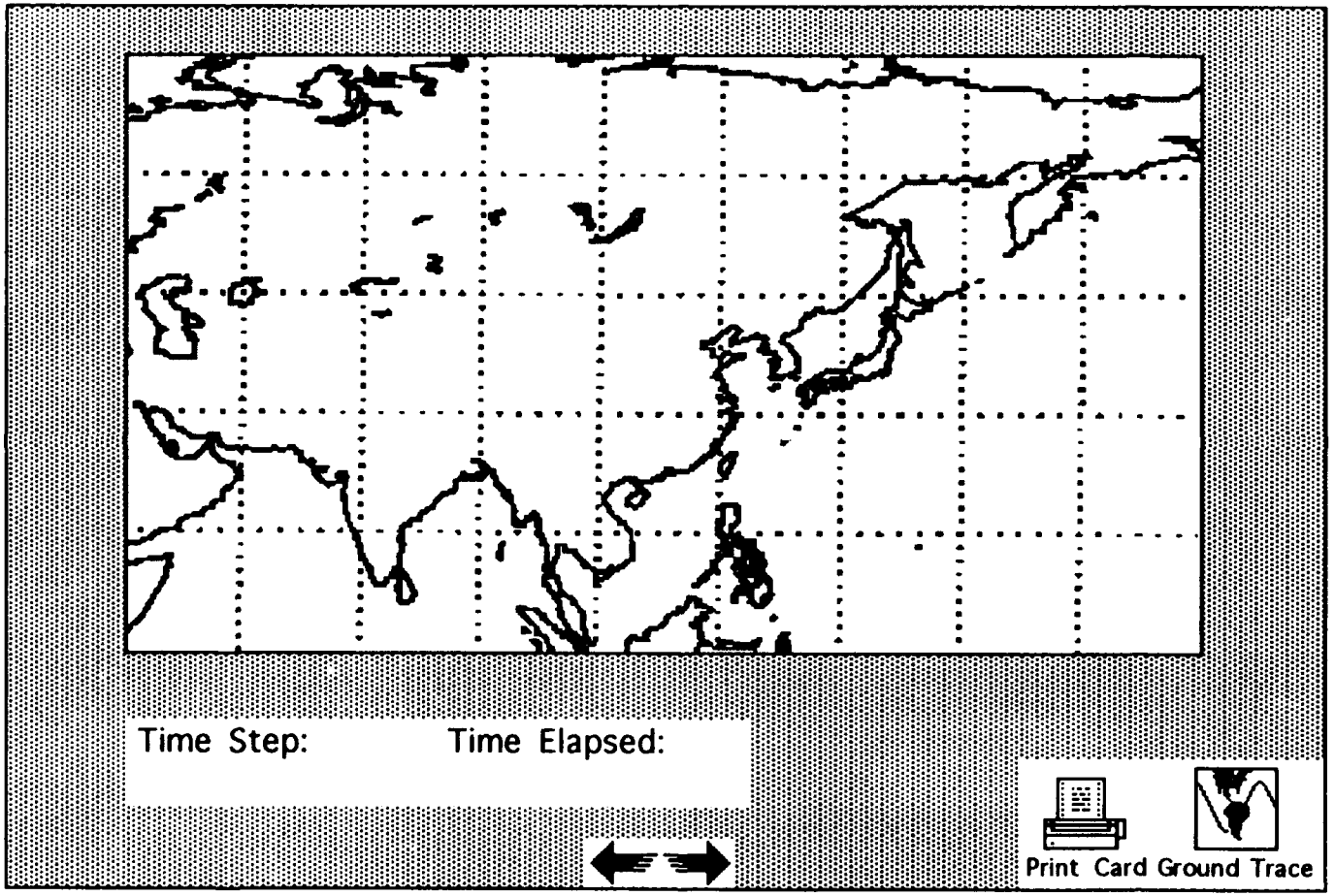

Time Step:
Time Elapsed:
Print Card
Ground Trace

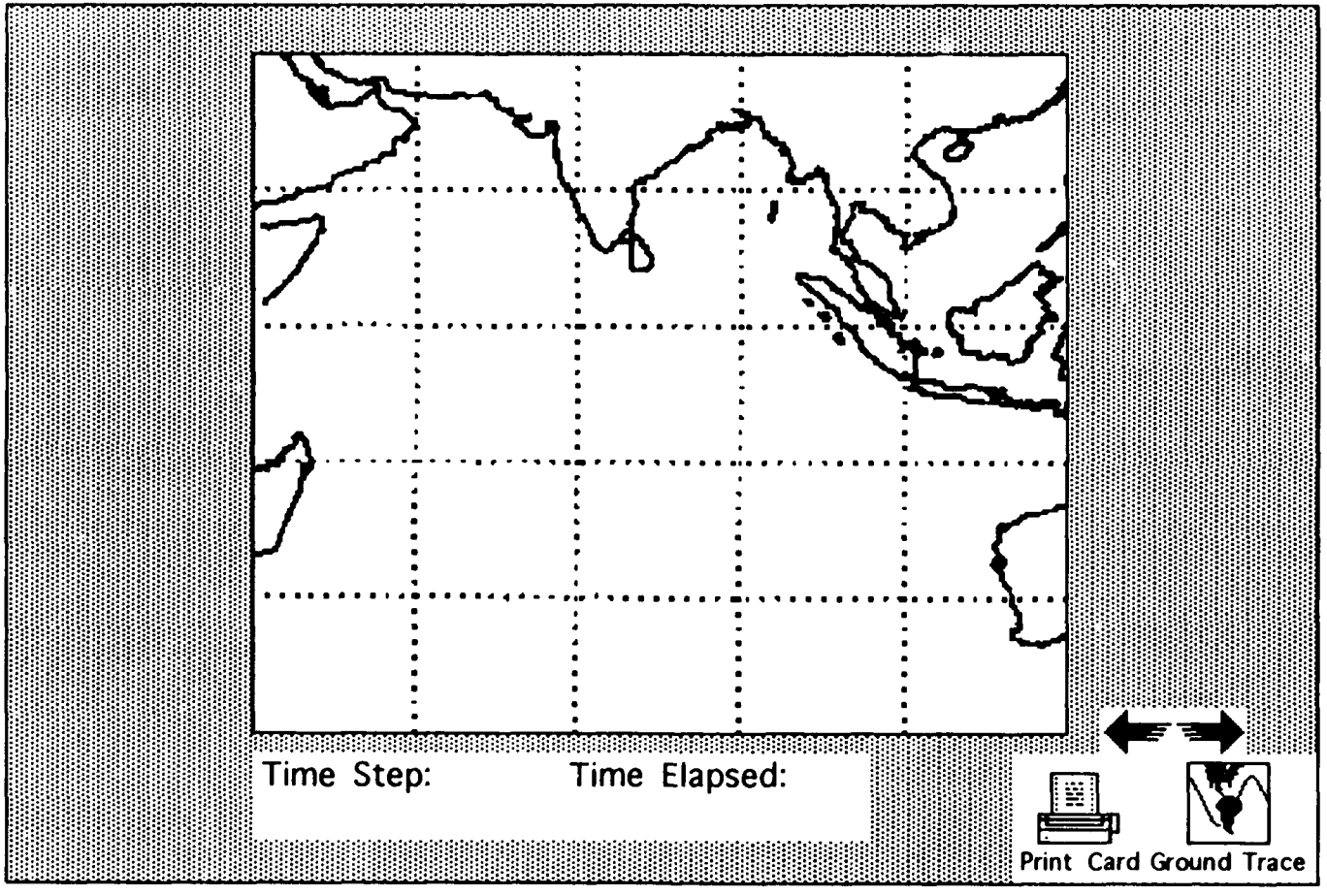

Time Step:
Time Elapsed:
Print Card
Ground Trace

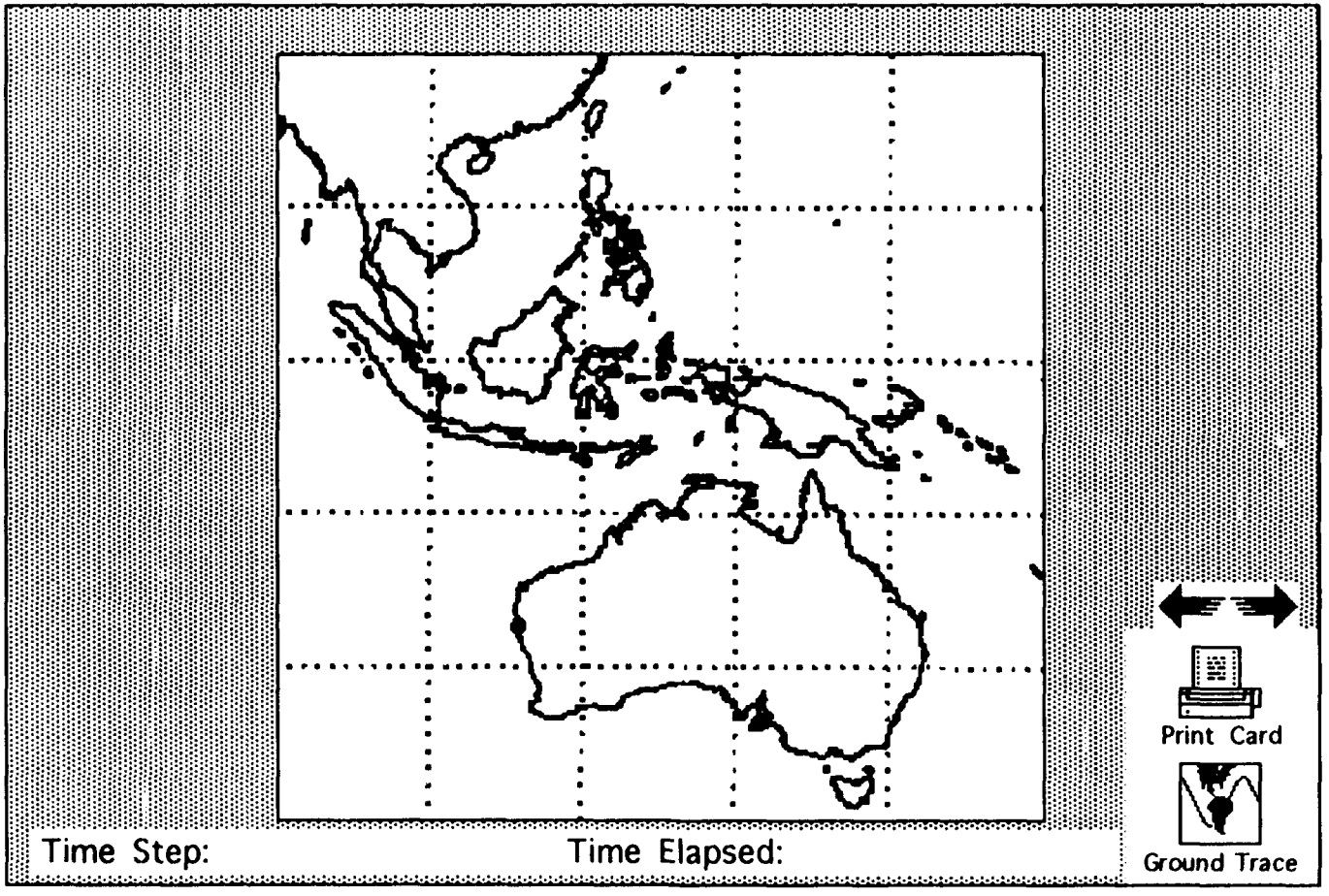

Time Step:
Time Elapsed:
Print Card
Ground Trace

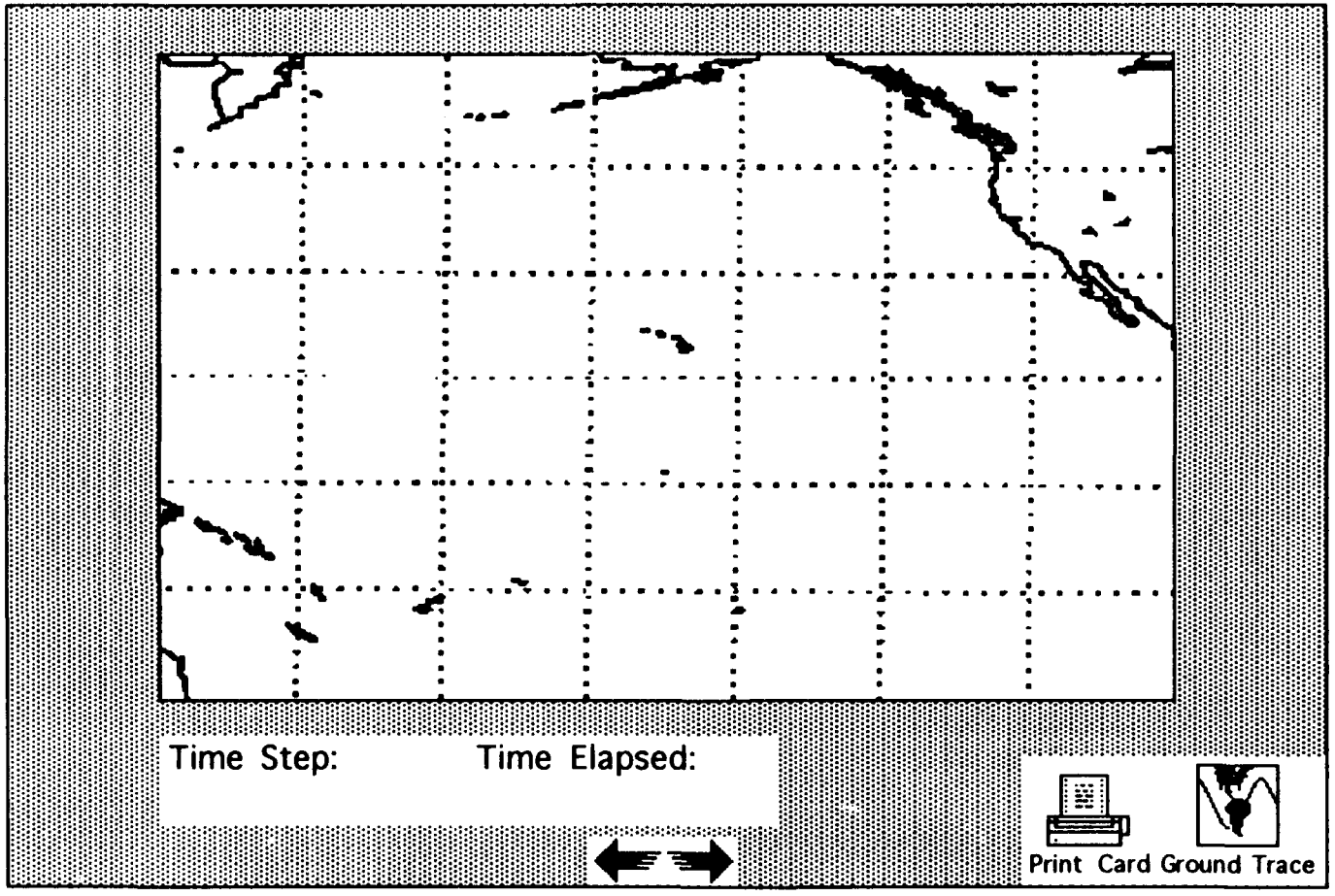

Time Step:
Time Elapsed:
Print Card
Ground Trace

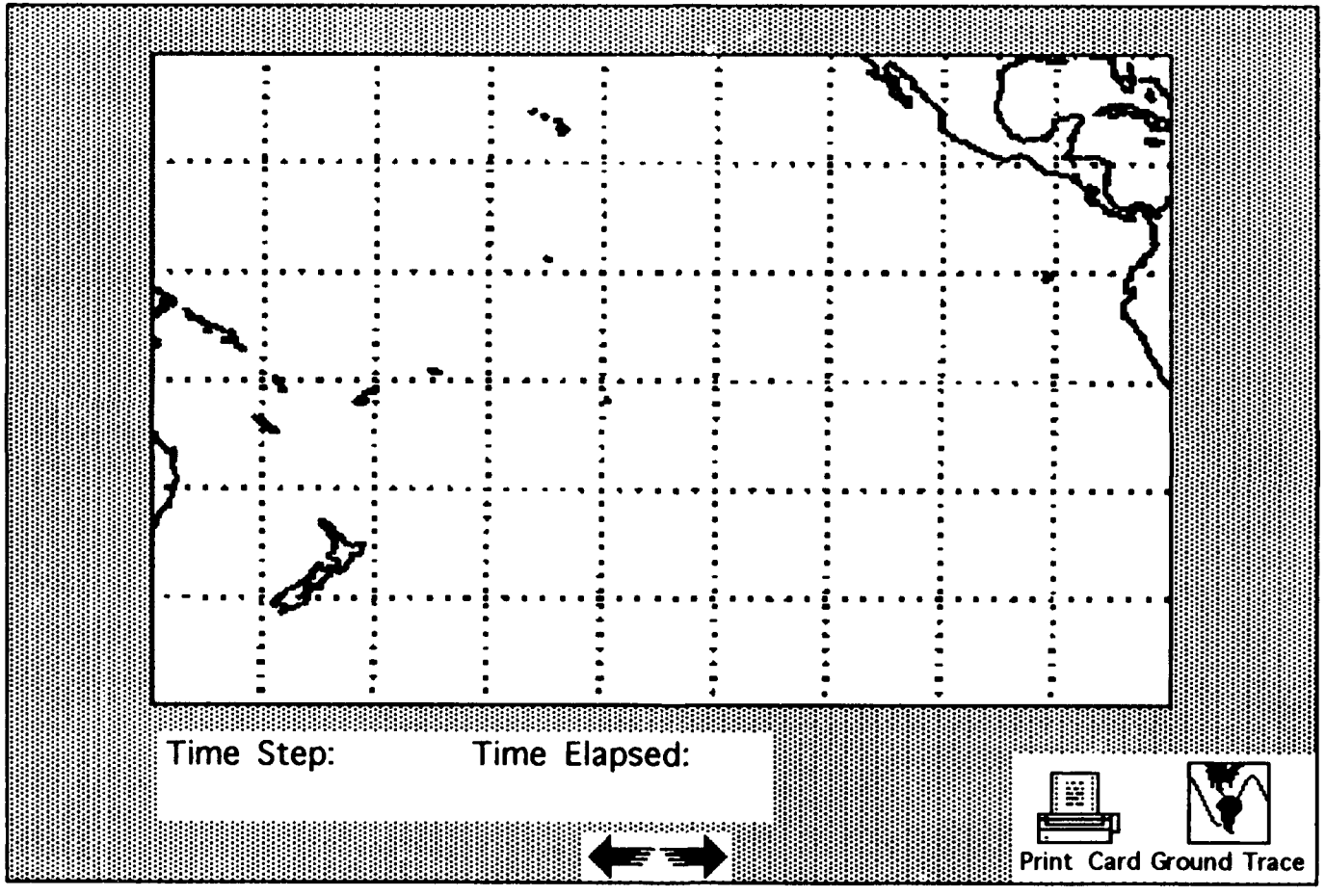

Time Step:
Time Elapsed:
Print Card
Ground Trace

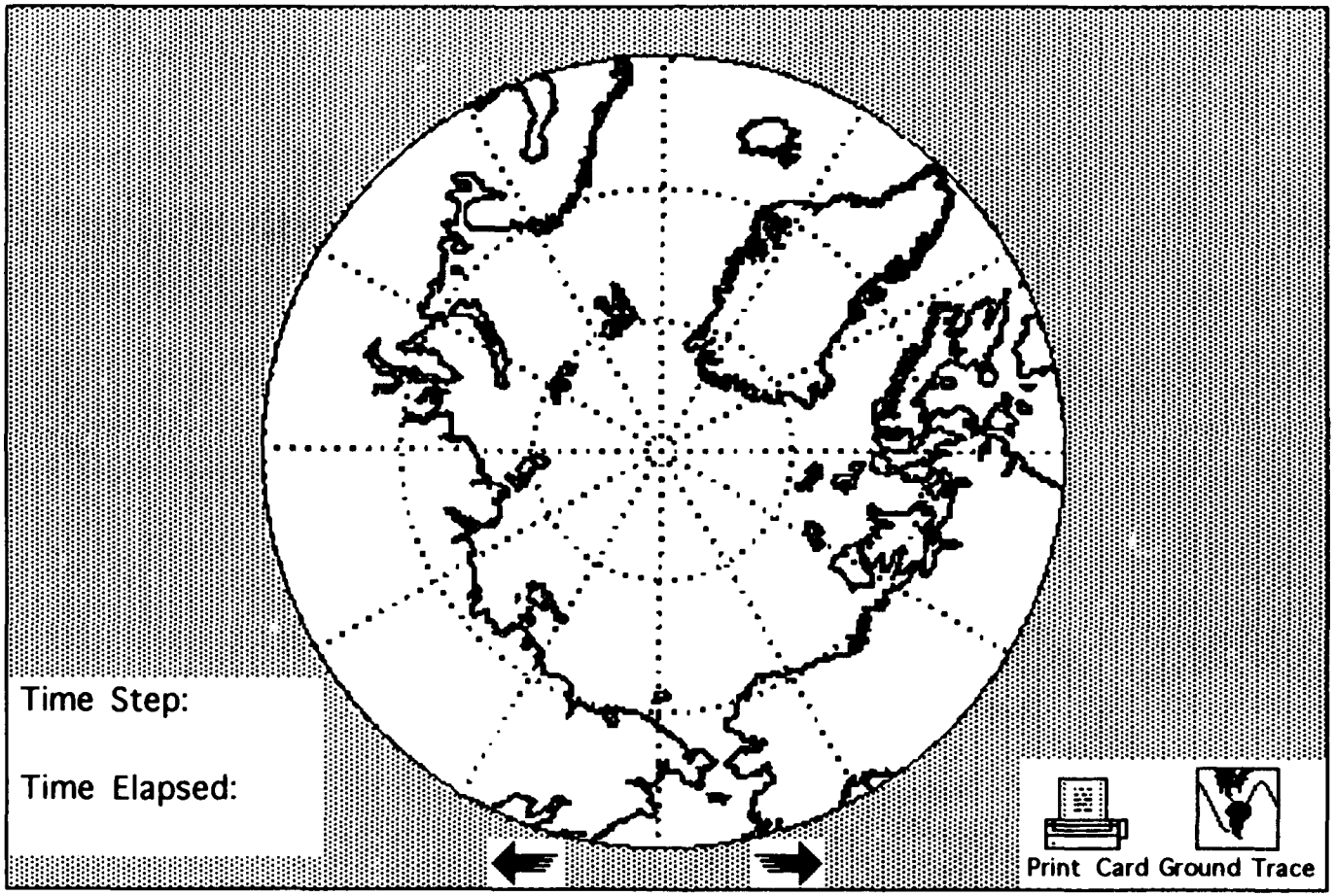

Time Step:
Time Elapsed:
Print Card
Ground Trace

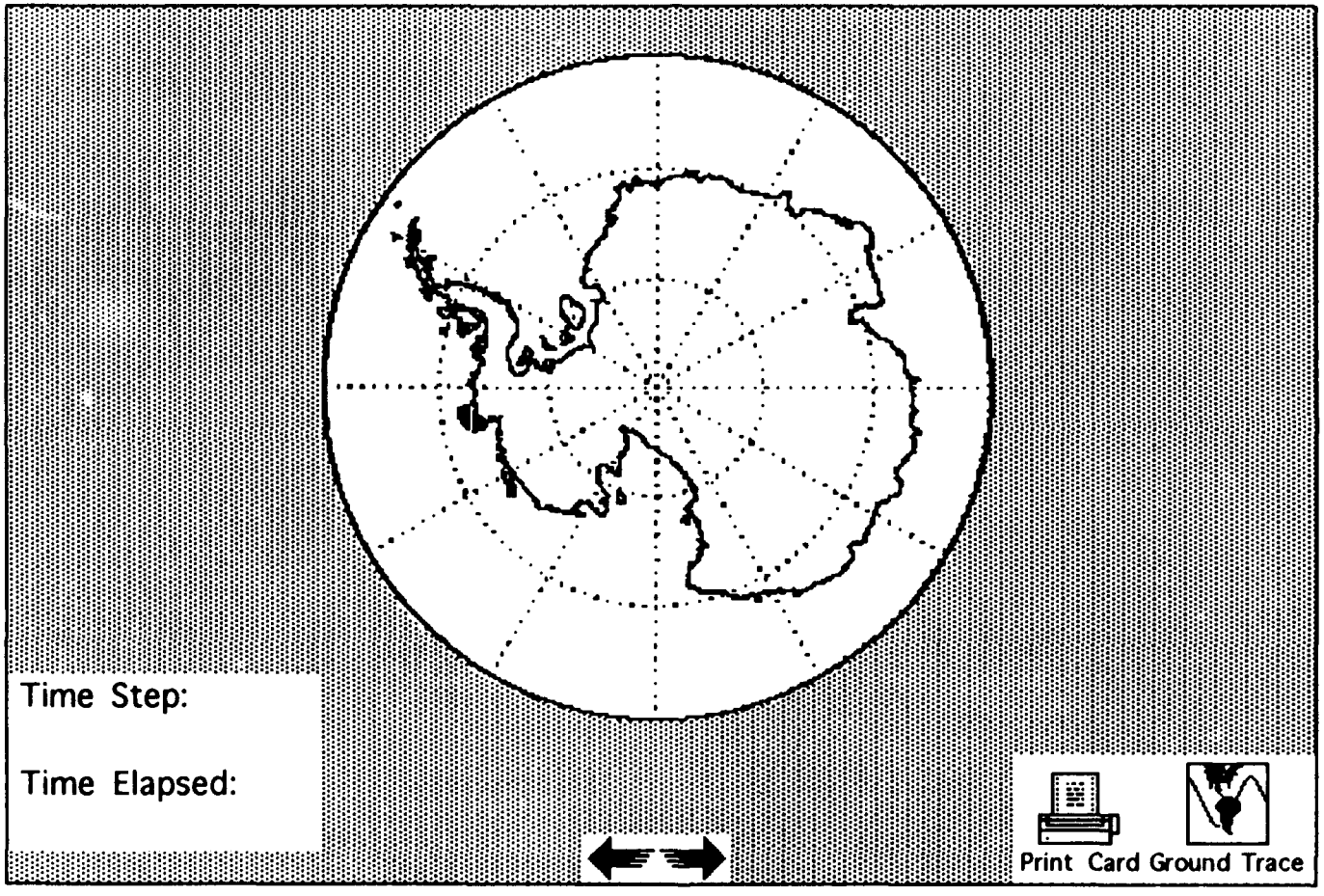

Time Step:
Time Elapsed:
Print Card
Ground Trace


Time Step:
Time Elapsed:
Print Card
Ground Trace


Time Step:
Time Elapsed:
Print Card
Ground Trace


Time Step:
Time Elapsed:
Print Card
Ground Trace


Time Step:
Time Elapsed:
Print Card
Ground Trace


Time Step:
Time Elapsed:
Print
Card
Ground Trace

Stack Information

Welcome to the "Help Me" portion of this program.
To use this program simply select any of the 'Big Three' buttons shown below.


Orbital Info


Ground Station


Link Info

Selection of any of these buttons will take the user to the appropriate section for entry of the information required to operate this program. The *logical sequence of selection* is first **'Orbital Info'** to enter the orbital information followed by **'Ground Info'**. The user is locked out of the **'Link Info'** section until the preceding two sections are complete. Additionally, any change in the first two sections will also lock the user out of the **'Link Info'** until both sections have been updated. Normally the user can tell if access to an option is denied by the appearance of a greyed button such as:

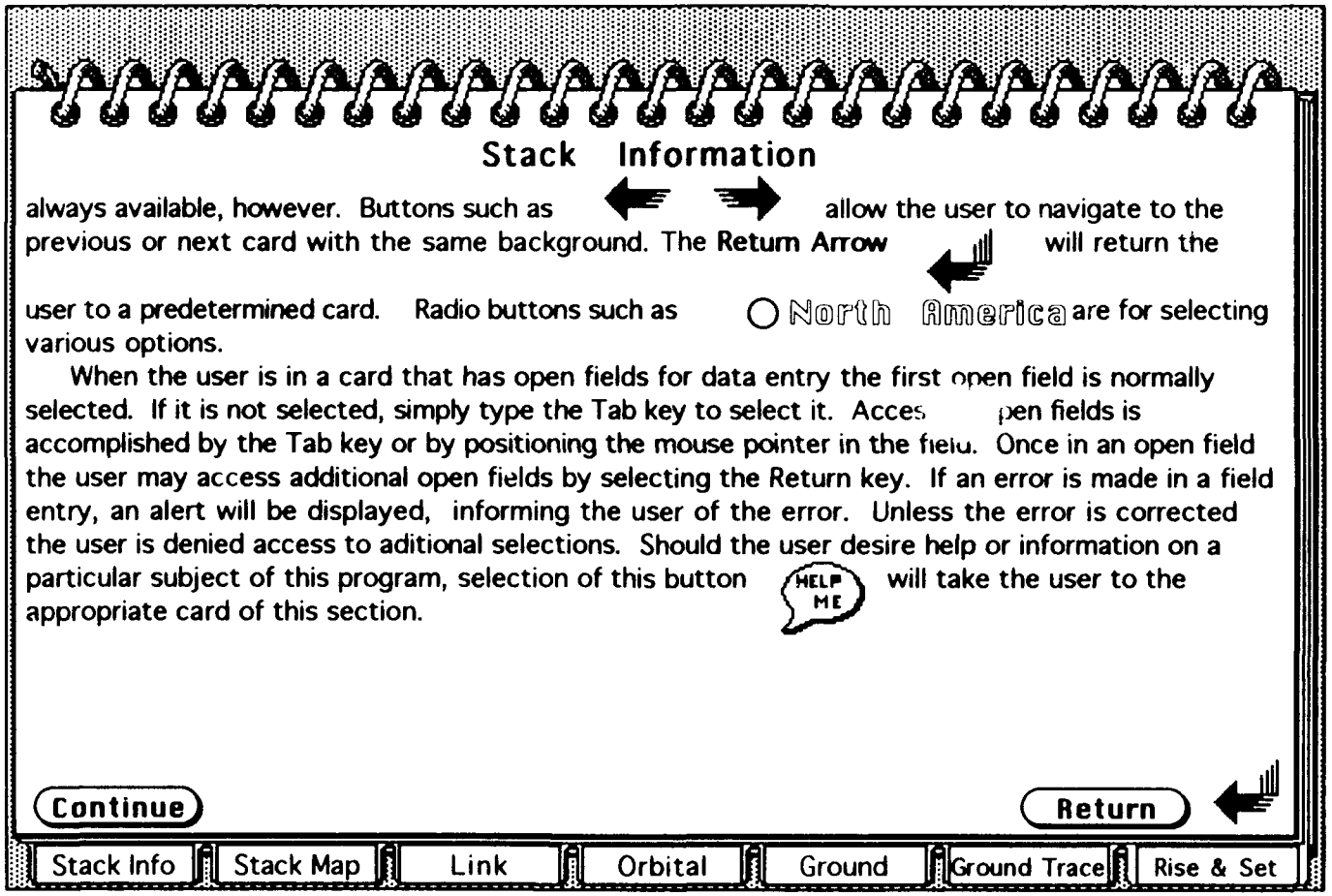

Link Info

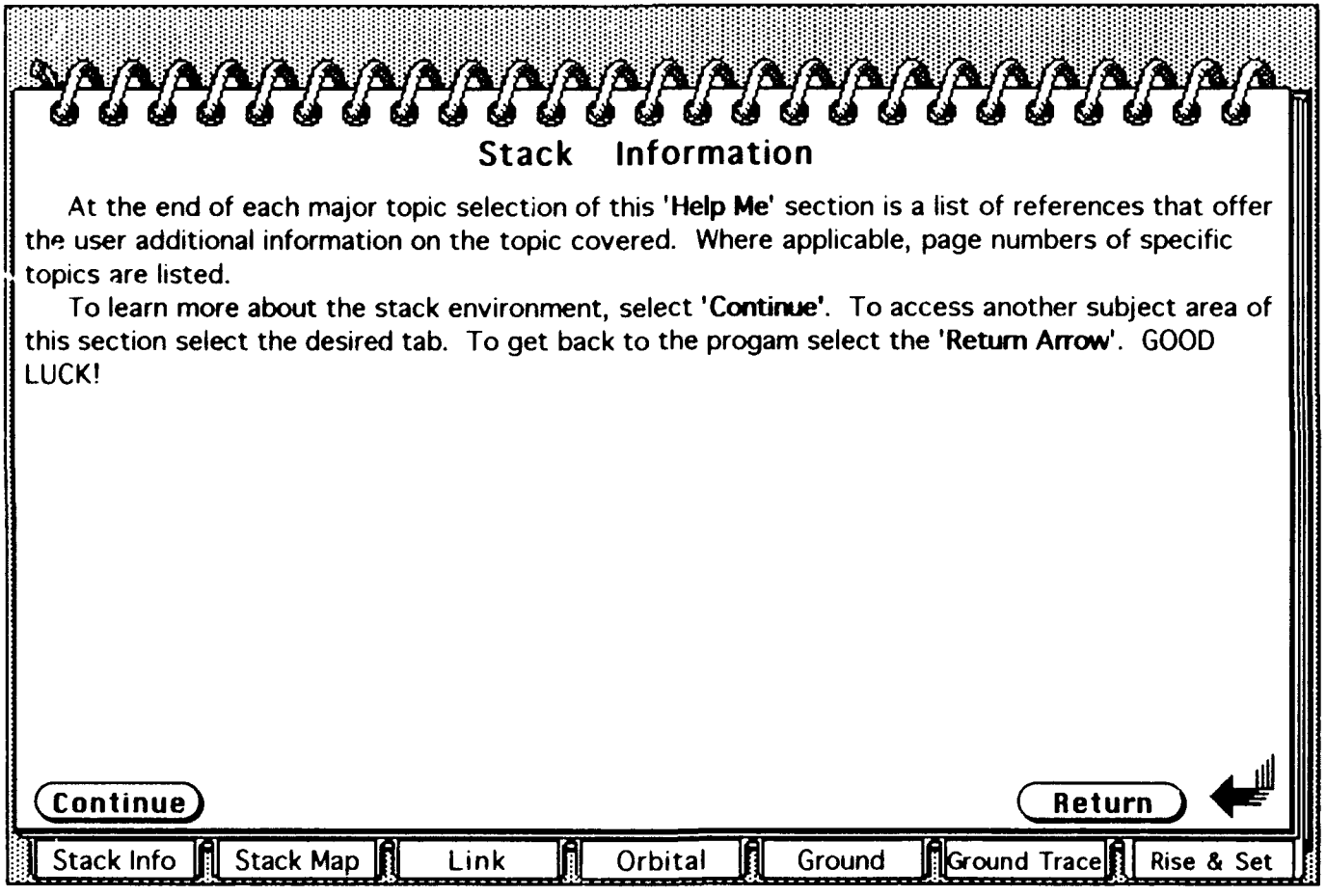
The other condition that will deny the user access to additional selections is an uncorrected error in an entry. Selection of the 'Help Me' section is

Continue



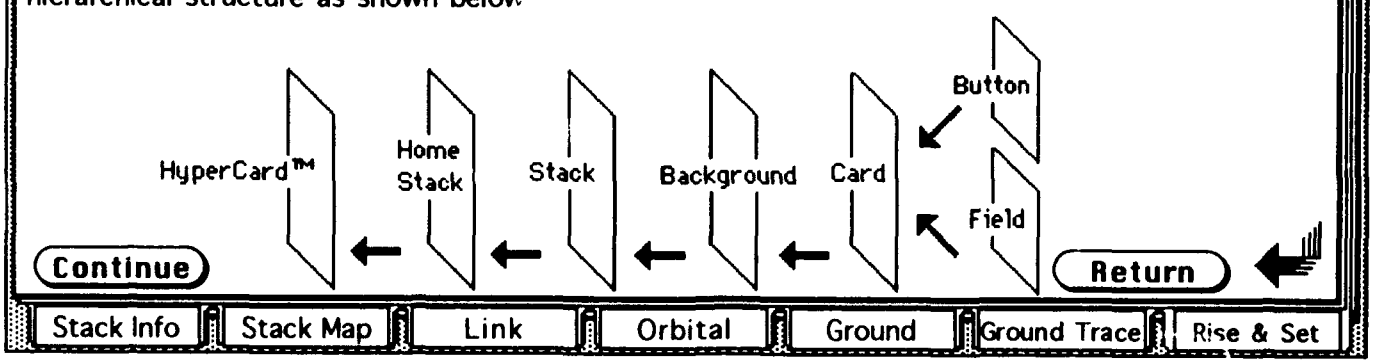
Stack Info | Stack Map | Link | Orbital | Ground | Ground Trace | Rise & Set


Stack Information
always available, however. Buttons such as allow the user to navigate to the previous or next card with the same background. The Return Arrow will return the user to a predetermined card. Radio buttons such as North America are for selecting various options.
When the user is in a card that has open fields for data entry the first open field is normally selected. If it is not selected, simply type the Tab key to select it. Acces pen fields is accomplished by the Tab key or by positioning the mouse pointer in the field. Once in an open field the user may access additional open fields by selecting the Return key. If an error is made in a field entry, an alert will be displayed, informing the user of the error. Unless the error is corrected the user is denied access to aditional selections. Should the user desire help or information on a particular subject of this program, selection of this button HELP ME will take the user to the appropriate card of this section.
Continue
Return
Stack Info
Stack Map
Link
Orbital
Ground
Ground Trace
Rise & Set


Stack Information
At the end of each major topic selection of this 'Help Me' section is a list of references that offer the user additional information on the topic covered. Where applicable, page numbers of specific topics are listed.
To learn more about the stack environment, select 'Continue'. To access another subject area of this section select the desired tab. To get back to the progam select the 'Return Arrow'. GOOD LUCK!
Continue
Return
Stack Info
Stack Map
Link
Orbital
Ground
Ground Trace
Rise & Set

The HyperCard™ Environment

This program is designed for use with HyperCard ™ version 2.0 or higher. HyperCard ™ is an object oriented program that utilizes buttons to initiate action. HyperCard ™ is designed very much like a rolodex in that it is made up of a stack of cards. Each card contains various fields, buttons and pictures that are overlaid upon a background which also may contain separate fields, buttons and pictures. This text resides in a background field. The background picture is a spiral notebook with tabs at the bottom. On each tab lies a button. When the user 'clicks' the mouse on the button (referred to as 'selects' from here on) a message handler written into the script of the button will bring the card described by the button's name to the top of the stack. These message handlers can reside in the scripts of HyperCard ™ objects (buttons, fields, cards, backgrounds and stacks). These scripts are transparent to the user. The operation of HyperCard ™ is based upon a hierarchical structure as shown below

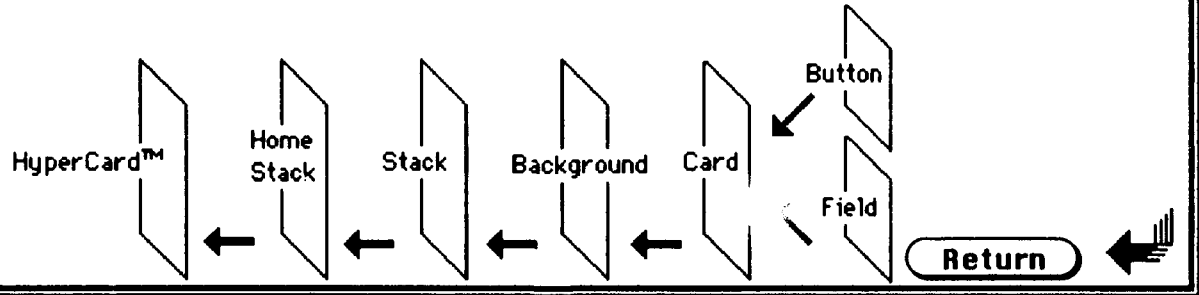


The HyperCard™ Environment

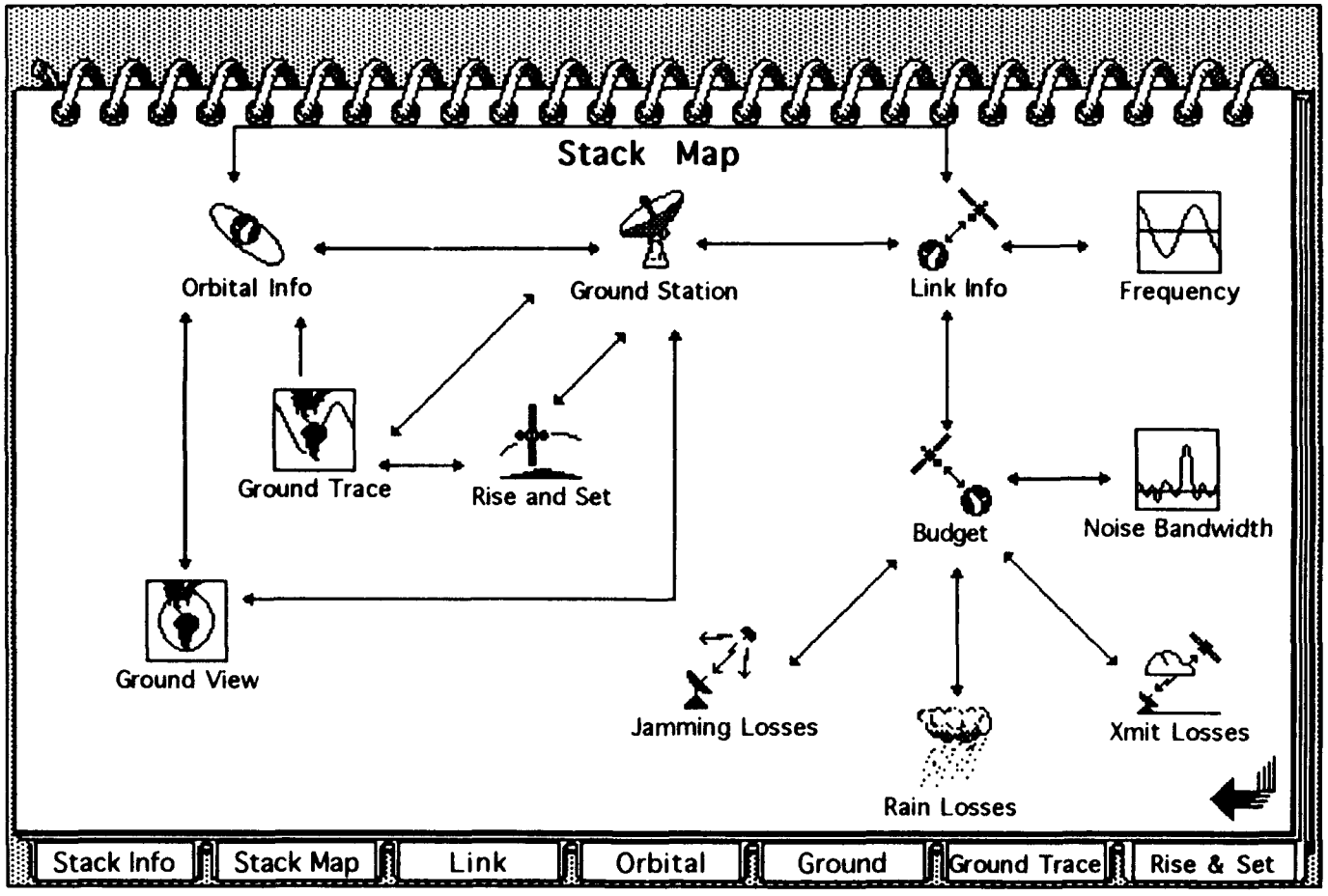
As HyperCard ™ operates, various system messages, such as 'Open Card' or 'Mouse Up', are passed through the hierarchy. Handlers can be written for any of the HyperCard ™ objects that will execute based upon the system messages. Additionally, separate handlers can be written for later execution. These handlers must reside at or above the object executing the call. This means that a script in a card cannot call for a handler in another card or a button but it may call upon a handler in its background. HyperCard ™ is a trademark of ©Apple Computer, Inc., Cupertino, CA

Reference:

1. Goodman, Danny, **The Complete HyperCard 2.0 Handbook**, Bantam Books, 1990



Stack Info | Stack Map | Link | Orbital | Ground | Ground Trace | Rise & Set


Stack Map
Orbital Info
Ground Station
Link Info
Frequency
Ground Trace
Rise and Set
Budget
Noise Bandwidth
Ground View
Jamming Losses
Xmit Losses
Rain Losses
Stack Info
Stack Map
Link
Orbital
Ground
Ground Trace
Rise & Set

Communications Link Information

Displayed on the 'Link Information' card are the four basic communications parameters required to analyze the communications system performance. They are the the ground transmitter's Effective Isotropic Radiated Power (EIRP) , the satellite receiver's figure of merit (the antenna gain-to-system noise temperature ratio or G/T), the satellite transmitter's EIRP and the ground receiver's G/T. These entries are assumed to be ideal values. If the specific EIRPs and G/Ts are not available and the user has access to more detailed parameters such as antenna gain, transmitter power and system noise temperature, then select the '... **Unknown**' option below the entries. Any losses unique to the platform, such as pointing and alignment errors and maintenance margins, can be added elsewhere, but the derived EIRP and G/T values will remain ideal. The logical sequence for entry or unknown query is to start with the ground transmitter and proceed clockwise. When all of the entries are satisfactorily completed, select '**Ideal Budget**' to examine the system performance.

<u>References:</u>

1. Gordon,Gary D. and Morgan,Walter L., **Communications Satellite Handbook**, John Wiley & Sons Inc, 1989

2. Ha, TriT., **Digital Satellite Communications, Second Edition**, McGraw-Hill Publishing Company, 1990



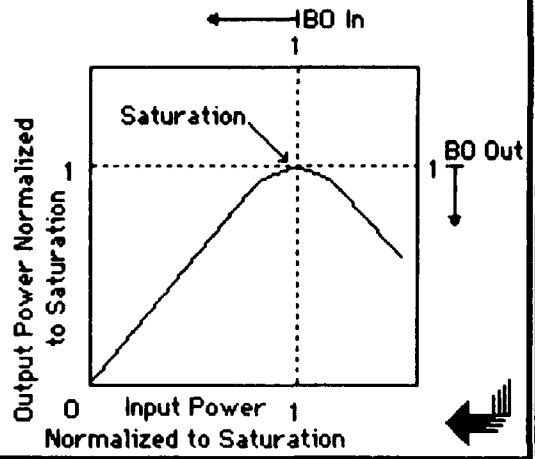
Stack Info | Stack Map | Link | EIRP | G/T | Budget | Freq

EIRP Information

When the user selects the '... **EIRP Unknown**' option from the 'Link Information' card, the 'EIRP Parameters' card is displayed. This card has several displays depending upon upon the opening criteria. The three items that remain constant are the the 'Transmitter Power' (Watts or dBW), 'Antenna Gain' (dBi) and '... Output Backoff' (dB) entries. The 'Transmitter Power' is the saturated power delivered by the transmitter amplifier to the antenna port.

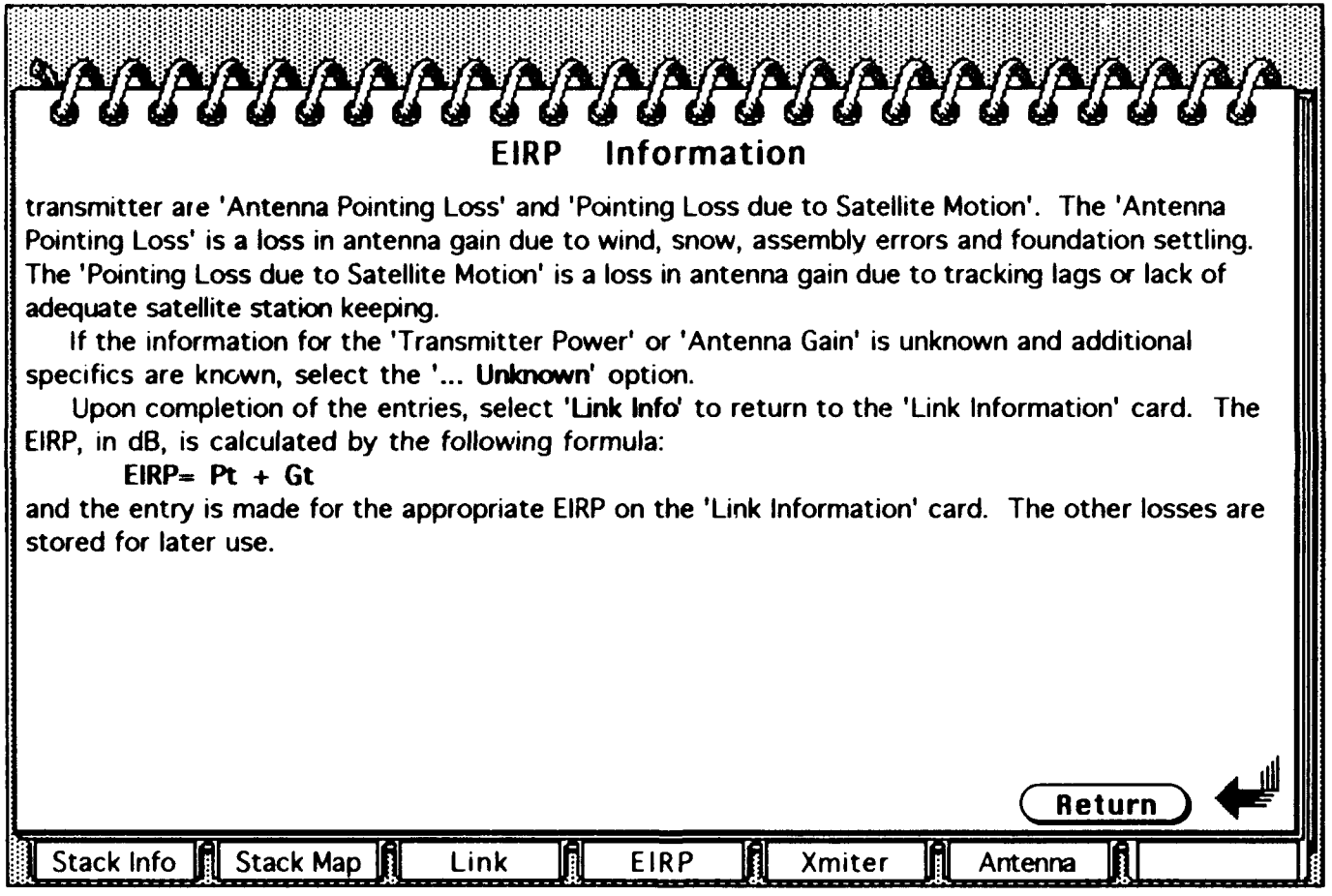
The '... Ouput Backoff' may be [illegible]ired to avoid nonlinear distortions that can occur in multi-carrier operations. If no backoff is required enter zero. An additional input for the 'Downlink Input Backoff' is available for the satellite transmitter when analysing the '**Geostationary**' option. Because a transponder/repeater type communications is assumed, there may be an additional requirement to backoff the power on the input to the satellite transmitter. If this input is not required, enter zero.

The other available entries available for the ground



Continue

Stack Info | Stack Map | Link | EIRP | Xmiter | Antenna


EIRP Information
transmitter are 'Antenna Pointing Loss' and 'Pointing Loss due to Satellite Motion'. The 'Antenna Pointing Loss' is a loss in antenna gain due to wind, snow, assembly errors and foundation settling. The 'Pointing Loss due to Satellite Motion' is a loss in antenna gain due to tracking lags or lack of adequate satellite station keeping.
If the information for the 'Transmitter Power' or 'Antenna Gain' is unknown and additional specifics are known, select the '... Unknown' option.
Upon completion of the entries, select 'Link Info' to return to the 'Link Information' card. The EIRP, in dB, is calculated by the following formula:
EIRP= Pt + Gt
and the entry is made for the appropriate EIRP on the 'Link Information' card. The other losses are stored for later use.
Return
Stack Info
Stack Map
Link
EIRP
Xmiter
Antenna

Transmitter Information

Upon selecting '**Transmitter Power Unknown**' on the '... EIRP Parameters' card, the user is presented with the '... Transmitter Parameters' card. Three basic inputs are required for calculation of the transmitter power. They are the 'Saturated Power Rating' (dBW or Watts), the 'Reserve for end-of-life loss' (dB), and the 'Feeder Loss' (dB).

The 'Saturated Power Rating' is the ideal saturated power output by the transmitter as specified by the manufacturer. The 'Reserve for end-of-life loss' is an engineering factor from the manufacturer that assumes a degradation of output over the life of the transmitter. The 'Feeder Loss' are losses due to directional couplers, switches, filters, and antenna feeds.

If the transmitter is the ground site, an additional entry, 'Transmission Line Loss' (dB), provides for losses due to the waveguide or coax cable from the transmitter to the antenna. Because the satellite transmitter and antenna are assumed to be located together, that loss is discounted.

The transmitter power in dBW is calculated by the following formula:

Pt = Psat - Leol - Lf

Upon completion of these entries, select '**Transmitter**' to return to the '... EIRP Parameters' card. The program will then display the calculated transmitter power in dBW.

Stack Info | Stack Map | Link | EIRP | Xmiter | Antenna

G/T Information

Upon selecting '...**G/T Unknown**' from the 'Link Information' card, the user is presented with the '... G/T Parameters' card. Two basic entries are available here. The first is the 'System Noise Temperature' (dB°K or °K), and the second is the 'Antenna Gain' (dBi). The system noise temperature is the sum of the receiving antenna's effective temperature and the receiver's equivalent noise temperature.

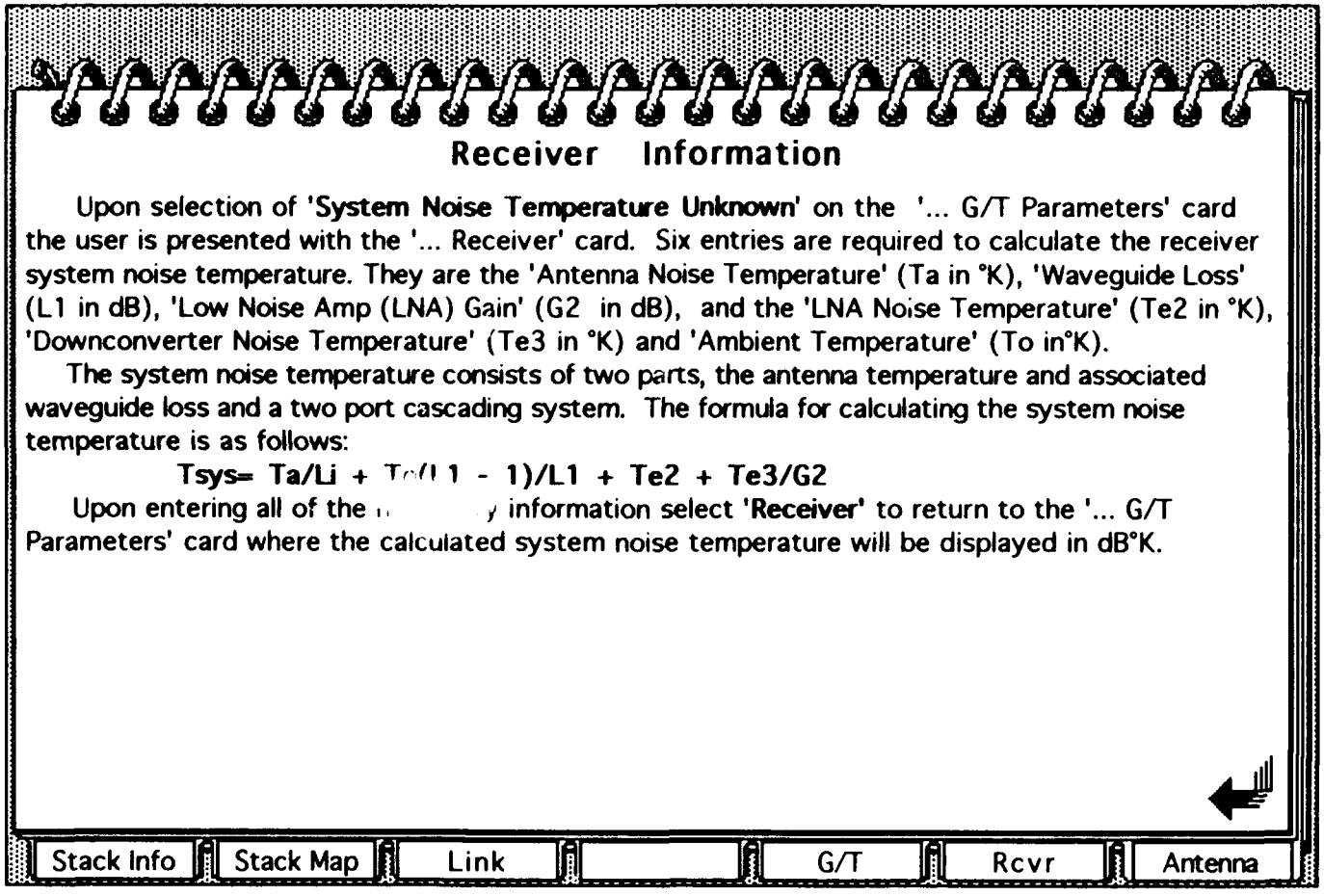
Additional losses are available for the ground station receiver. They are 'Maintenance Margin', 'Antenna Pointing Loss' and 'Pointing Loss due to Satellite Motion'. The maintenance margin is the change in system noise temperature due to periodic maintenance. The 'Antenna Pointing Loss' is a loss in antenna gain due to wind, snow, assembly errors and foundation settling. The 'Pointing Loss due to Satellite Motion' is a loss in antenna gain due to tracking lags or lack of adequate satellite station keeping. All entries are in dB.

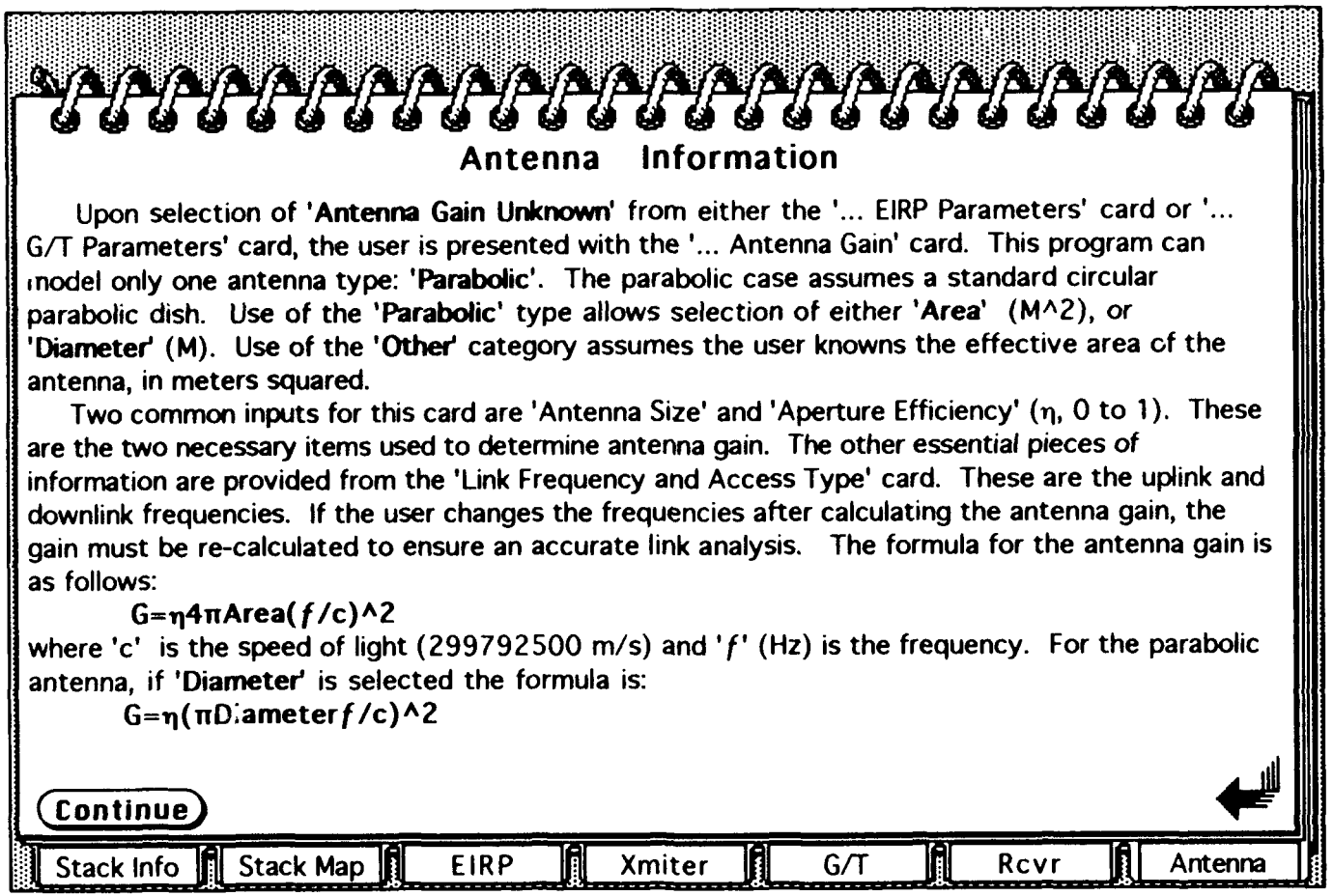
The G/T, in dB/°K, is calculated by the following formula:

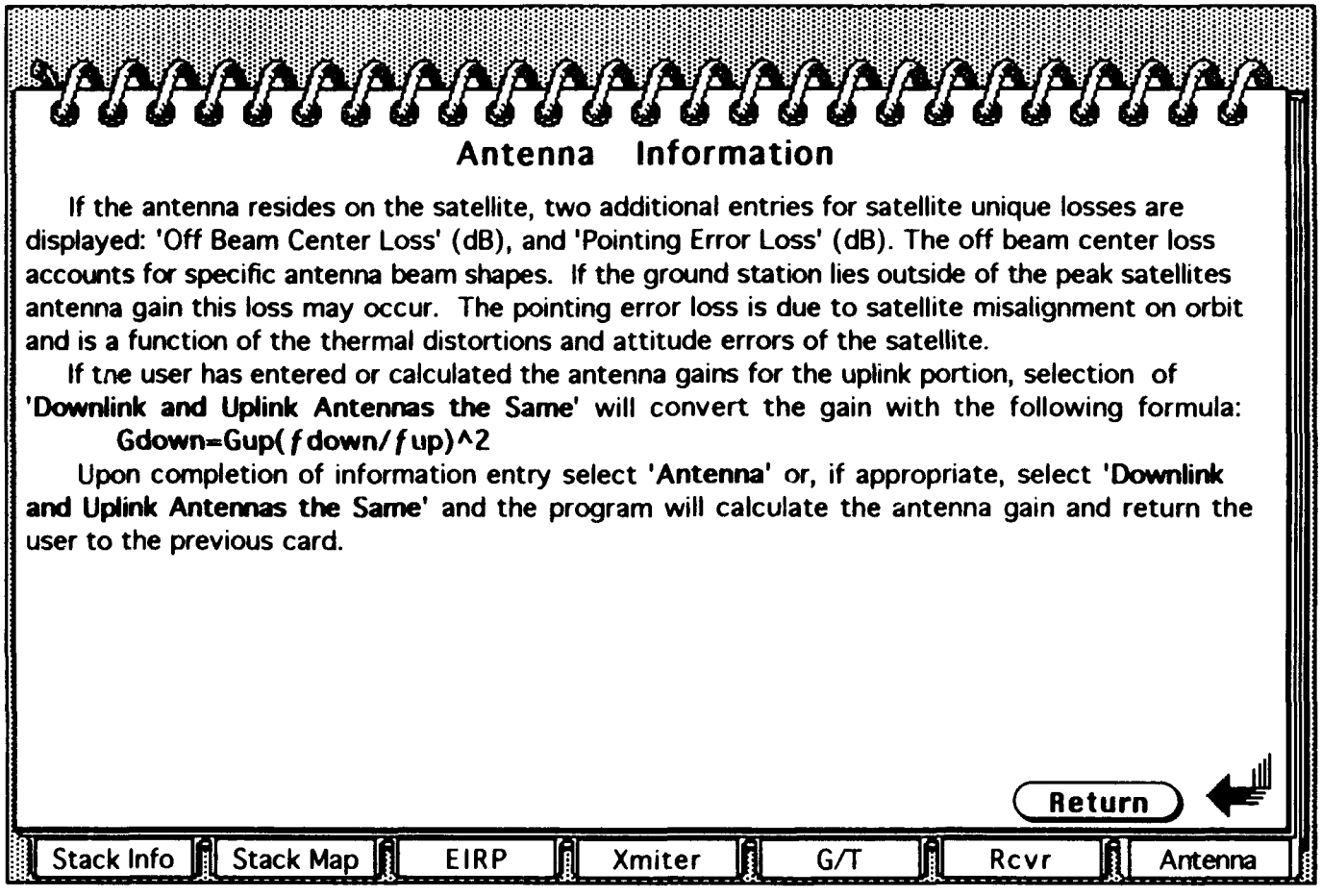
G/T= Gr - Tsys

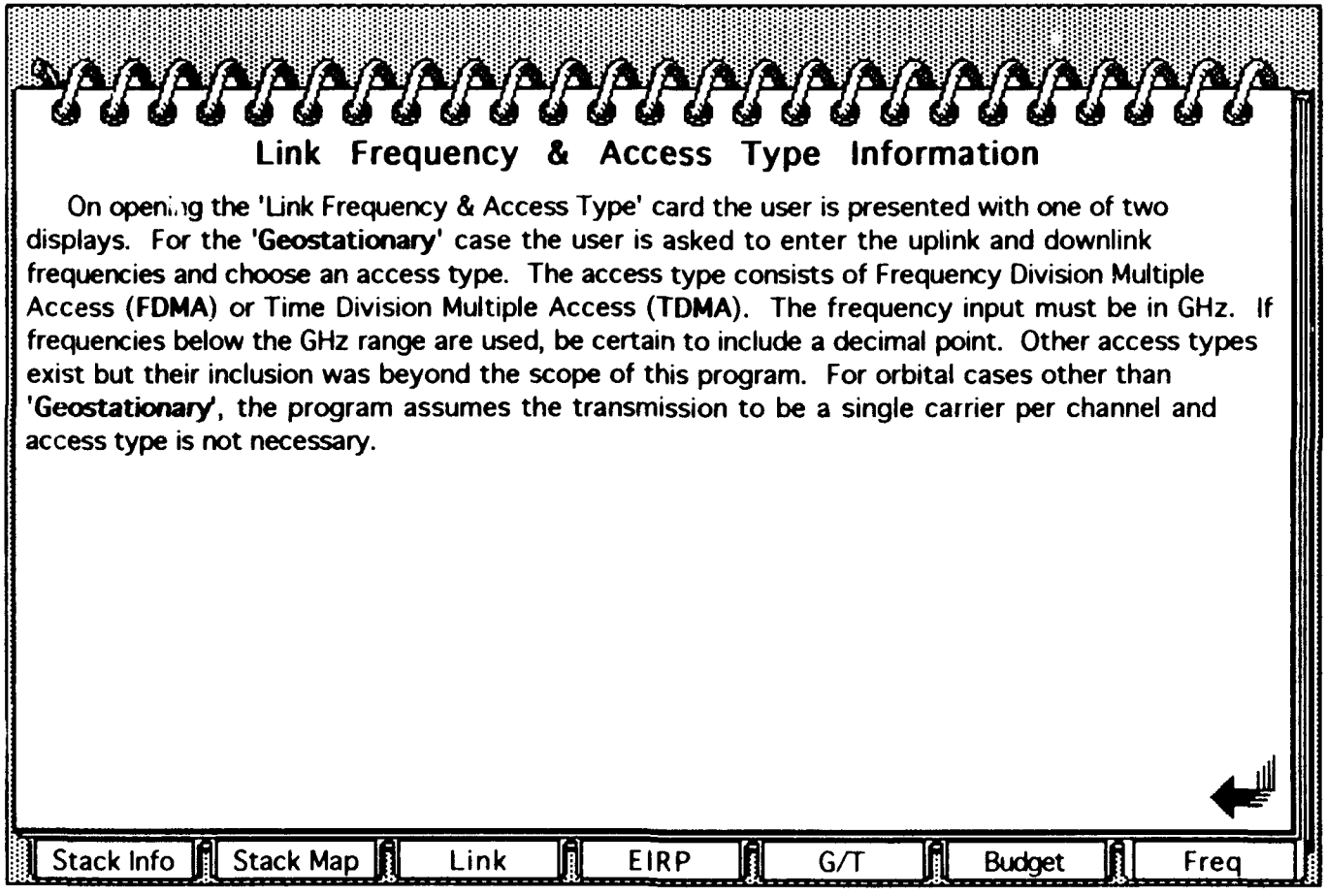
Upon entering all the parameters, select '**Link Info**' to return to the 'Link Information' card where the calculated G/T will displayed in the appropriate display.

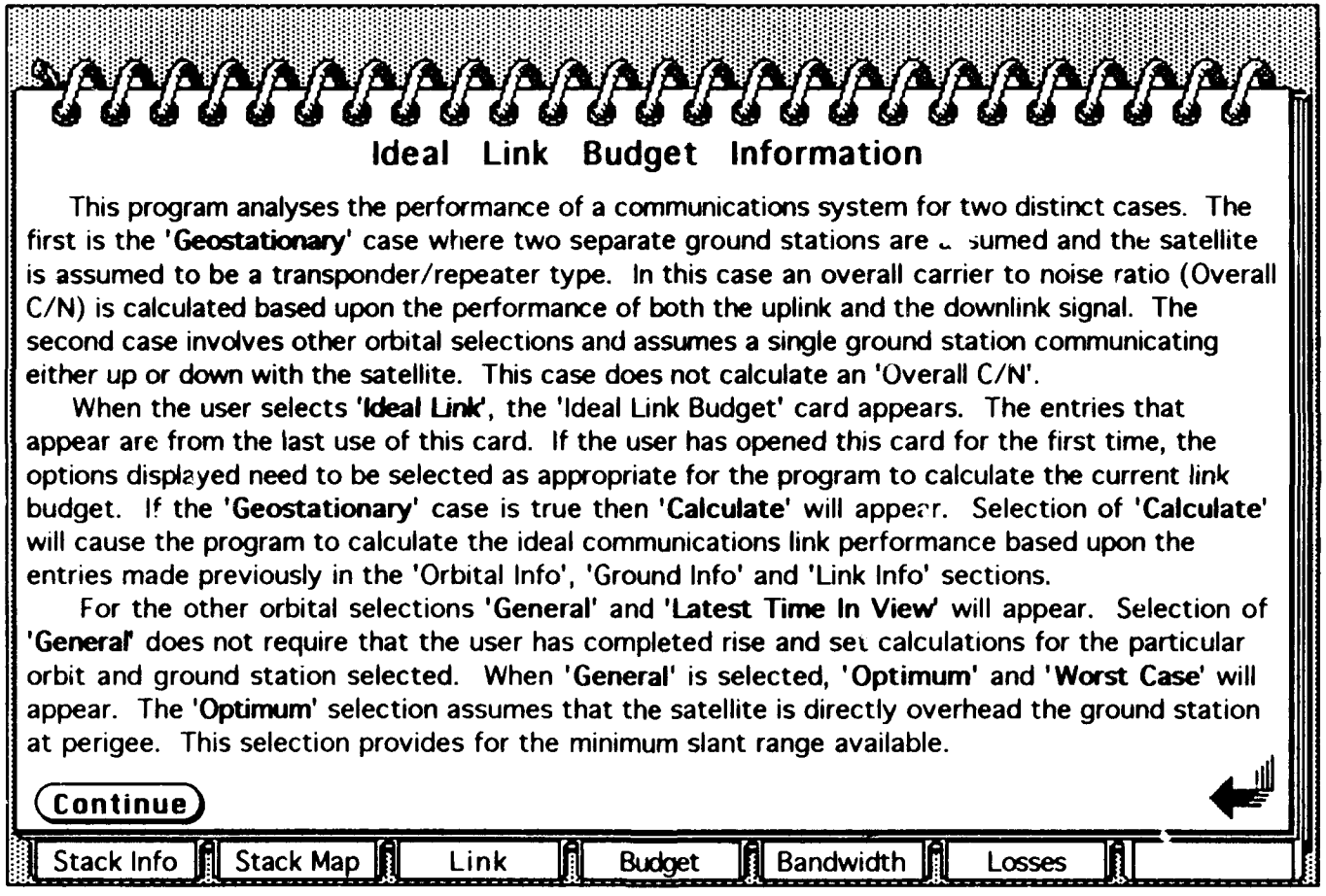


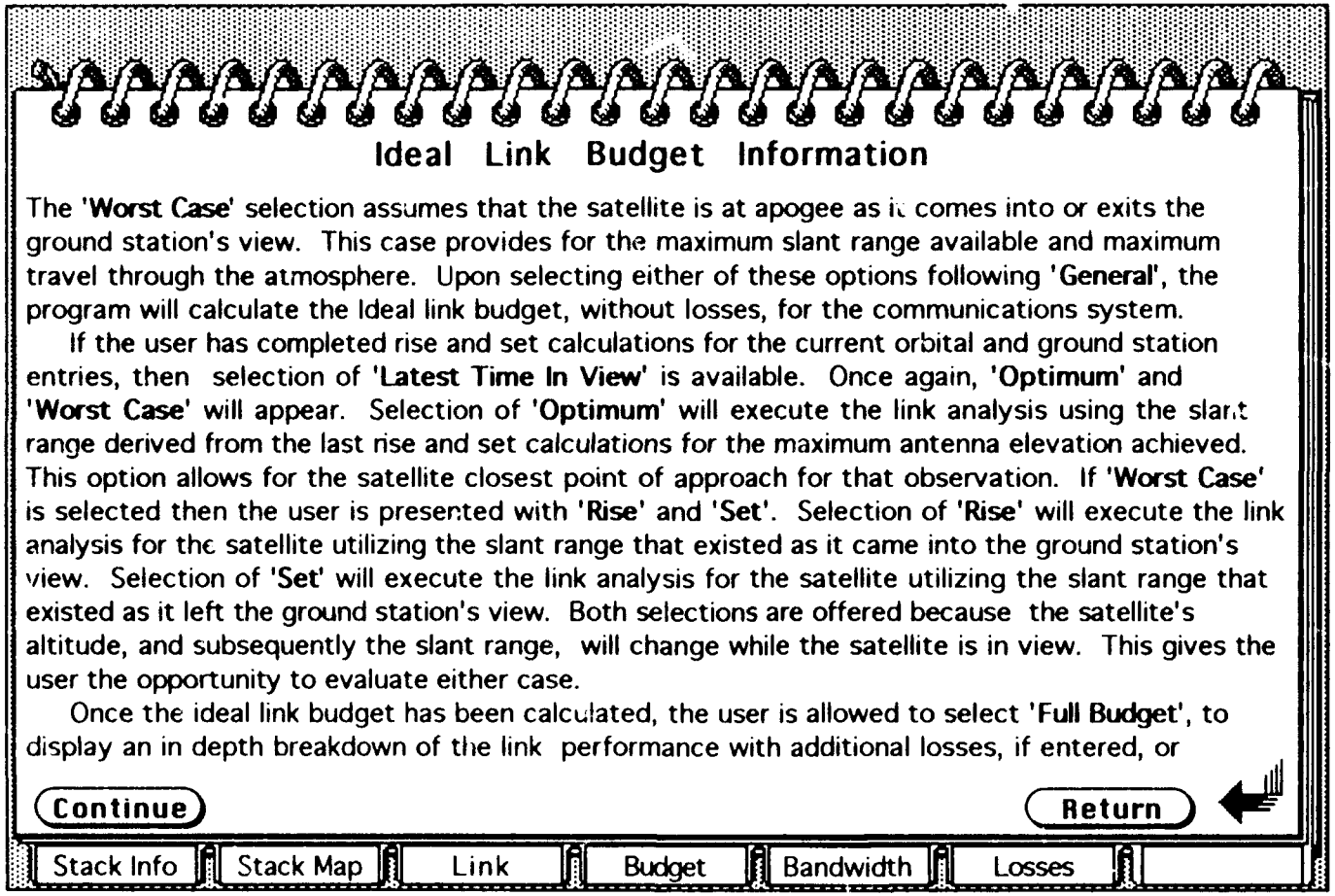

Receiver Information
Upon selection of 'System Noise Temperature Unknown' on the '... G/T Parameters' card the user is presented with the '... Receiver' card. Six entries are required to calculate the receiver system noise temperature. They are the 'Antenna Noise Temperature' (Ta in °K), 'Waveguide Loss' (L1 in dB), 'Low Noise Amp (LNA) Gain' (G2 in dB), and the 'LNA Noise Temperature' (Te2 in °K), 'Downconverter Noise Temperature' (Te3 in °K) and 'Ambient Temperature' (To in°K).
The system noise temperature consists of two parts, the antenna temperature and associated waveguide loss and a two port cascading system. The formula for calculating the system noise temperature is as follows:
Tsys= Ta/Li + To(L1 - 1)/L1 + Te2 + Te3/G2
Upon entering all of the information select 'Receiver' to return to the '... G/T Parameters' card where the calculated system noise temperature will be displayed in dB°K.
Stack Info
Stack Map
Link
G/T
Rcvr
Antenna

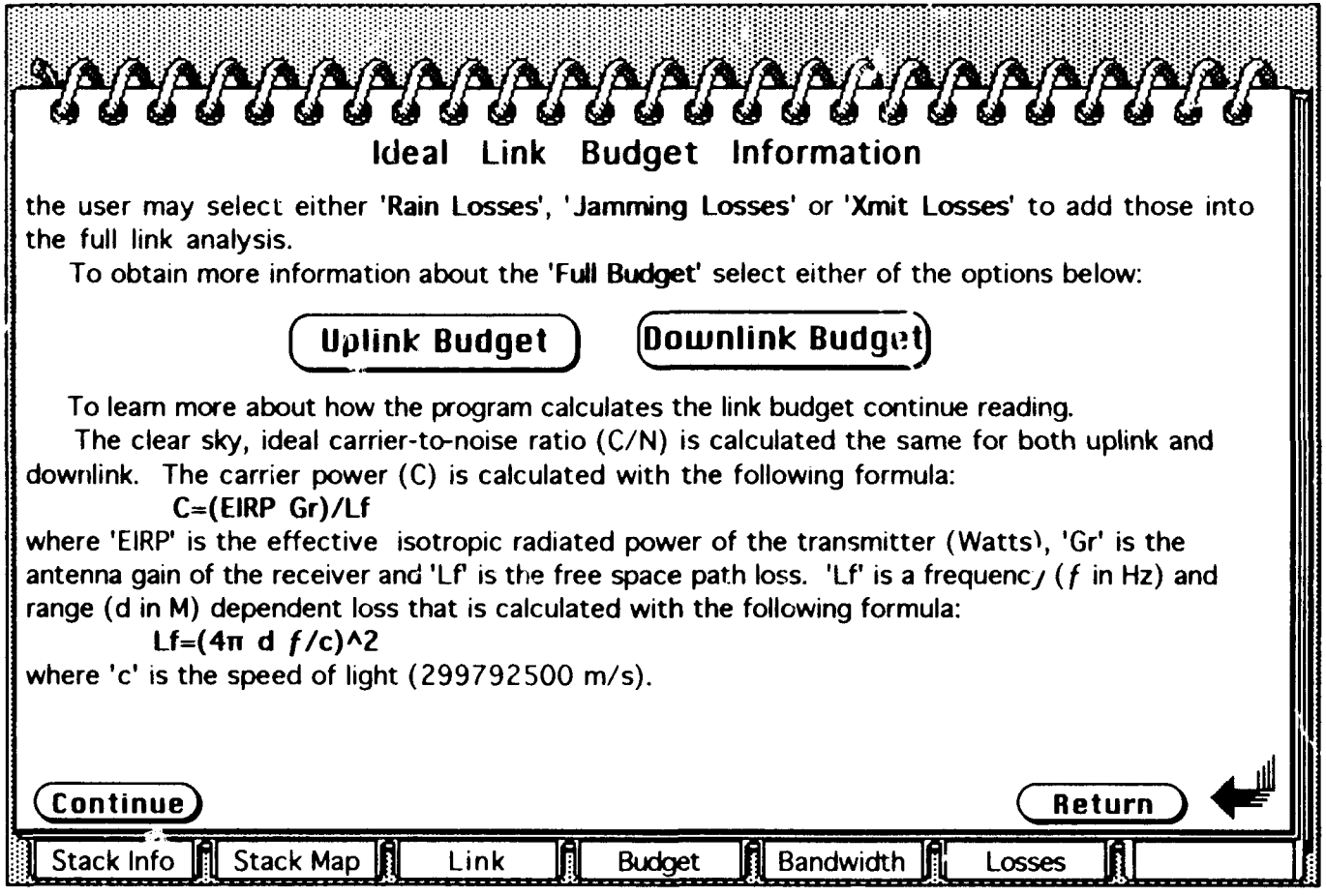

Antenna Information
Upon selection of 'Antenna Gain Unknown' from either the '... EIRP Parameters' card or '... G/T Parameters' card, the user is presented with the '... Antenna Gain' card. This program can model only one antenna type: 'Parabolic'. The parabolic case assumes a standard circular parabolic dish. Use of the 'Parabolic' type allows selection of either 'Area' (M^2), or 'Diameter' (M). Use of the 'Other' category assumes the user knowns the effective area of the antenna, in meters squared.
Two common inputs for this card are 'Antenna Size' and 'Aperture Efficiency' (η, 0 to 1). These are the two necessary items used to determine antenna gain. The other essential pieces of information are provided from the 'Link Frequency and Access Type' card. These are the uplink and downlink frequencies. If the user changes the frequencies after calculating the antenna gain, the gain must be re-calculated to ensure an accurate link analysis. The formula for the antenna gain is as follows:
G=η4πArea(f/c)^2
where 'c' is the speed of light (299792500 m/s) and 'f' (Hz) is the frequency. For the parabolic antenna, if 'Diameter' is selected the formula is:
G=η(πDiameterf/c)^2
Continue
Stack Info
Stack Map
EIRP
Xmiter
G/T
Rcvr
Antenna


Antenna Information
If the antenna resides on the satellite, two additional entries for satellite unique losses are displayed: 'Off Beam Center Loss' (dB), and 'Pointing Error Loss' (dB). The off beam center loss accounts for specific antenna beam shapes. If the ground station lies outside of the peak satellites antenna gain this loss may occur. The pointing error loss is due to satellite misalignment on orbit and is a function of the thermal distortions and attitude errors of the satellite.
If the user has entered or calculated the antenna gains for the uplink portion, selection of 'Downlink and Uplink Antennas the Same' will convert the gain with the following formula:
Gdown=Gup(f down/f up)^2
Upon completion of information entry select 'Antenna' or, if appropriate, select 'Downlink and Uplink Antennas the Same' and the program will calculate the antenna gain and return the user to the previous card.
Return
Stack Info
Stack Map
EIRP
Xmiter
G/T
Rcvr
Antenna


Link Frequency & Access Type Information
On opening the 'Link Frequency & Access Type' card the user is presented with one of two displays. For the 'Geostationary' case the user is asked to enter the uplink and downlink frequencies and choose an access type. The access type consists of Frequency Division Multiple Access (FDMA) or Time Division Multiple Access (TDMA). The frequency input must be in GHz. If frequencies below the GHz range are used, be certain to include a decimal point. Other access types exist but their inclusion was beyond the scope of this program. For orbital cases other than 'Geostationary', the program assumes the transmission to be a single carrier per channel and access type is not necessary.
Stack Info
Stack Map
Link
EIRP
G/T
Budget
Freq


Ideal Link Budget Information
This program analyses the performance of a communications system for two distinct cases. The first is the 'Geostationary' case where two separate ground stations are assumed and the satellite is assumed to be a transponder/repeater type. In this case an overall carrier to noise ratio (Overall C/N) is calculated based upon the performance of both the uplink and the downlink signal. The second case involves other orbital selections and assumes a single ground station communicating either up or down with the satellite. This case does not calculate an 'Overall C/N'.
When the user selects 'Ideal Link', the 'Ideal Link Budget' card appears. The entries that appear are from the last use of this card. If the user has opened this card for the first time, the options displayed need to be selected as appropriate for the program to calculate the current link budget. If the 'Geostationary' case is true then 'Calculate' will appear. Selection of 'Calculate' will cause the program to calculate the ideal communications link performance based upon the entries made previously in the 'Orbital Info', 'Ground Info' and 'Link Info' sections.
For the other orbital selections 'General' and 'Latest Time In View' will appear. Selection of 'General' does not require that the user has completed rise and set calculations for the particular orbit and ground station selected. When 'General' is selected, 'Optimum' and 'Worst Case' will appear. The 'Optimum' selection assumes that the satellite is directly overhead the ground station at perigee. This selection provides for the minimum slant range available.
Continue
Stack Info
Stack Map
Link
Budget
Bandwidth
Losses


Ideal Link Budget Information
The 'Worst Case' selection assumes that the satellite is at apogee as it comes into or exits the ground station's view. This case provides for the maximum slant range available and maximum travel through the atmosphere. Upon selecting either of these options following 'General', the program will calculate the Ideal link budget, without losses, for the communications system.
If the user has completed rise and set calculations for the current orbital and ground station entries, then selection of 'Latest Time In View' is available. Once again, 'Optimum' and 'Worst Case' will appear. Selection of 'Optimum' will execute the link analysis using the slant range derived from the last rise and set calculations for the maximum antenna elevation achieved. This option allows for the satellite closest point of approach for that observation. If 'Worst Case' is selected then the user is presented with 'Rise' and 'Set'. Selection of 'Rise' will execute the link analysis for the satellite utilizing the slant range that existed as it came into the ground station's view. Selection of 'Set' will execute the link analysis for the satellite utilizing the slant range that existed as it left the ground station's view. Both selections are offered because the satellite's altitude, and subsequently the slant range, will change while the satellite is in view. This gives the user the opportunity to evaluate either case.
Once the ideal link budget has been calculated, the user is allowed to select 'Full Budget', to display an in depth breakdown of the link performance with additional losses, if entered, or
Continue
Return
Stack Info
Stack Map
Link
Budget
Bandwidth
Losses


Ideal Link Budget Information
the user may select either 'Rain Losses', 'Jamming Losses' or 'Xmit Losses' to add those into the full link analysis.
To obtain more information about the 'Full Budget' select either of the options below:
Uplink Budget
Downlink Budget
To learn more about how the program calculates the link budget continue reading.
The clear sky, ideal carrier-to-noise ratio (C/N) is calculated the same for both uplink and downlink. The carrier power (C) is calculated with the following formula:
C=(EIRP Gr)/Lf
where 'EIRP' is the effective isotropic radiated power of the transmitter (Watts), 'Gr' is the antenna gain of the receiver and 'Lf' is the free space path loss. 'Lf' is a frequency (f in Hz) and range (d in M) dependent loss that is calculated with the following formula:
Lf=(4π d f/c)^2
where 'c' is the speed of light (299792500 m/s).
Continue
Return
Stack Info
Stack Map
Link
Budget
Bandwidth
Losses

Ideal Link Budget Information

The noise power (N) is a function of the receiver's system noise temperature (Tsys in °K) and noise bandwidth (BW in Hz). The noise power is calculated with the following formula:

N= Tsys k BW

where 'k' is the *Boltzmann Constant* (1.3803*10^-23 W/°K Hz). The basic inputs of this program are EIRP and G/T, therefore the C/N is calculated with the following formula:

C/N= (EIRP G/T)/(k BW Lf)

or in dB:

C/N= EIRP + G/T - (-228.6) - BW - Lf

where -228.6 is the Boltmann Constant in dBW/°K Hz.

The slant range is calculated for the '**Geostationary**' case when the user has selected '**Ground View**'. For the other orbital selections, the slant ranges are calculated during the rise and set calculation for '**Latest Time In View**' or for '**General**', upon selection of '**General**'. The basic formula for calculating the slant range (d) is:

d= [√(r^2 - Re^2 (cosE)^2)] - Re sinE

where 'r' is the radius of the satellite (Km), 'Re' is the radius of the earth (6378 Km), and 'E' is the antenna elevation (°).

Continue | Return

Stack Info | Stack Map | Link | Budget | Bandwidth | Losses

Ideal Link Budget Information

The 'Overall C/N' for the '**Geostationary**' case is calculated with the following formula:

Overall C/N= 1/[(1/Uplink C/N) + (1/Downlink C/N)]

<u>References:</u>

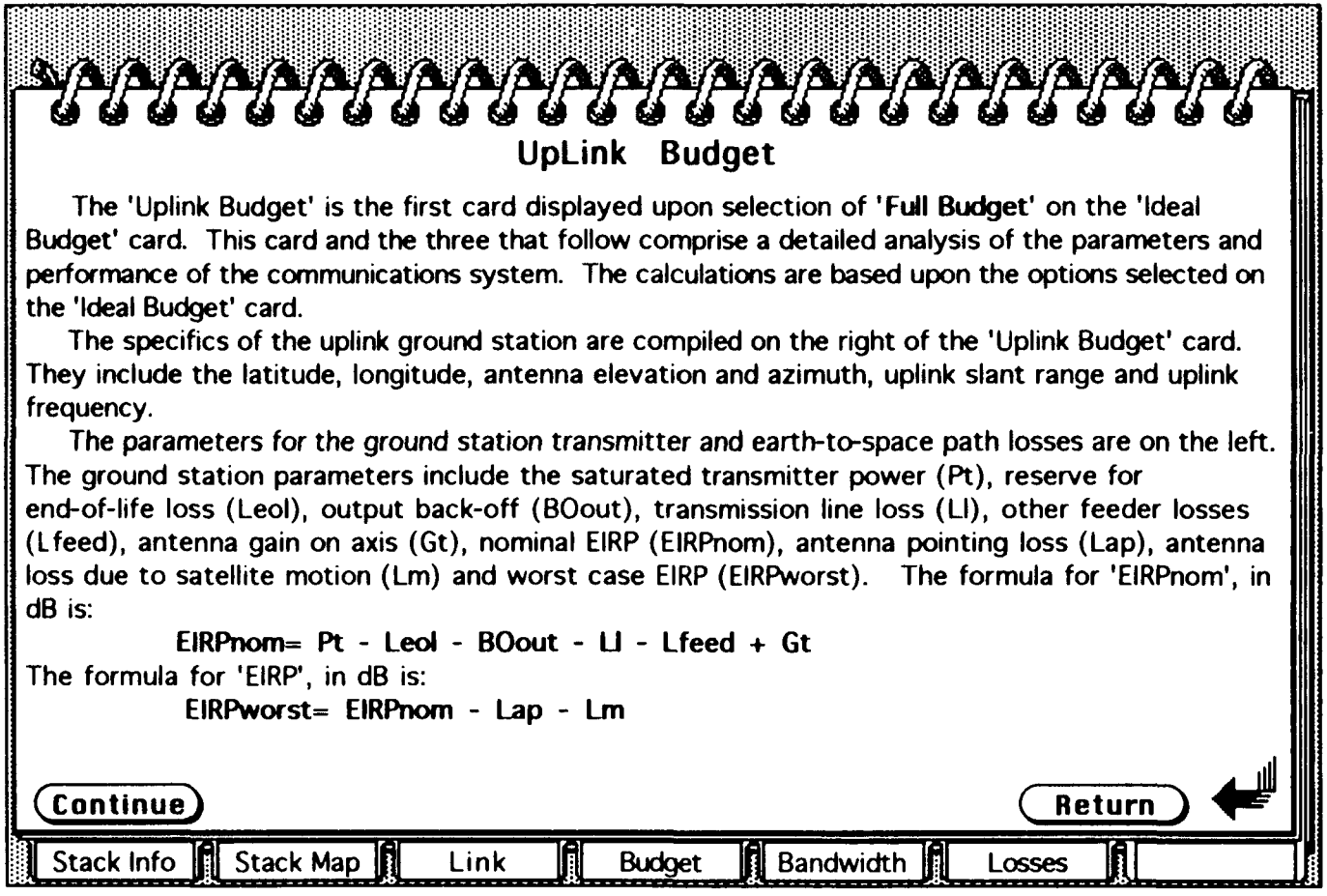
1. Gordon,Gary D. and Morgan,Walter L., **Communications Satellite Handbook,** John Wiley & Sons Inc, 1989

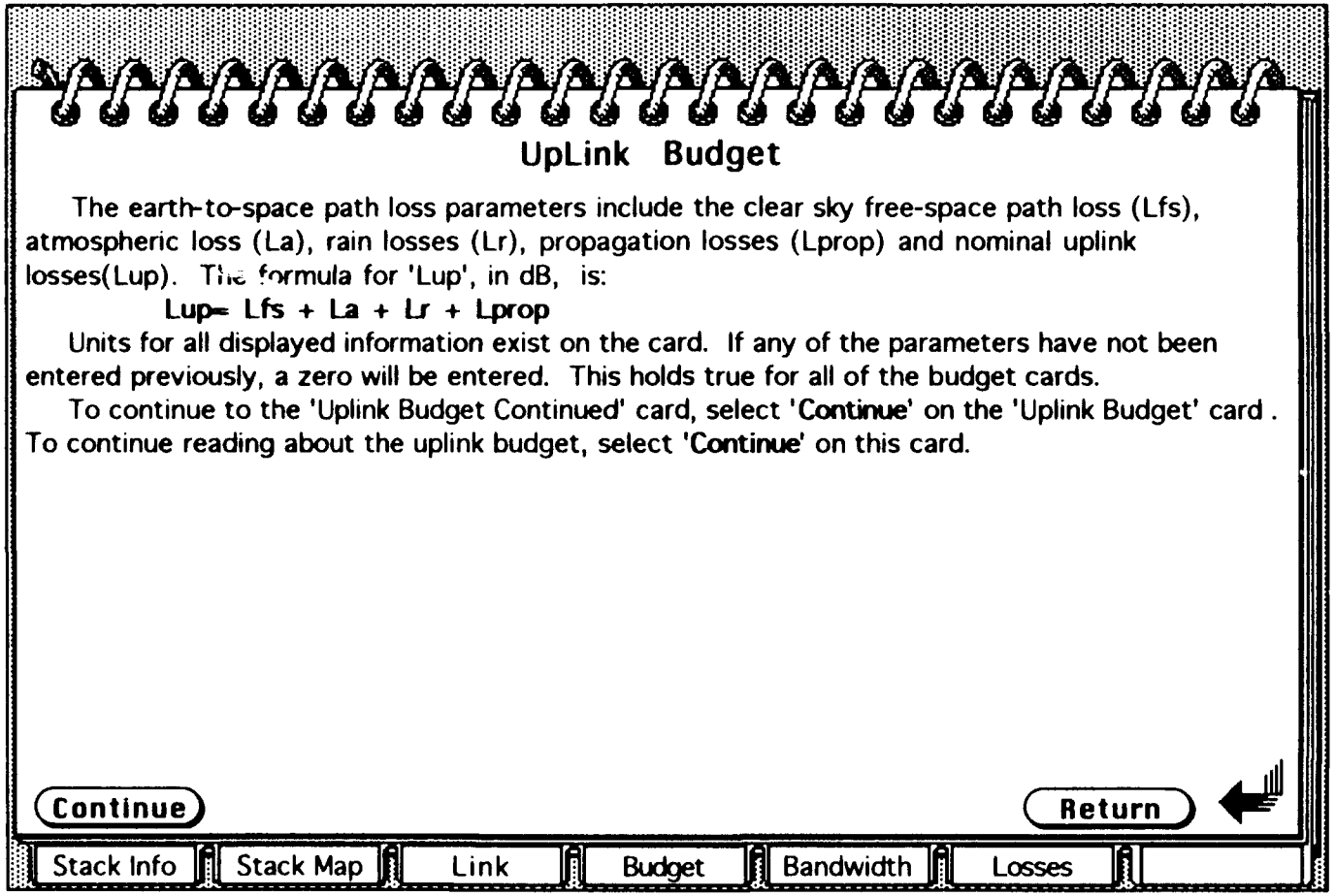
2. Ha, TriT., **Digital Satellite Communications, Second Edition,** McGraw-Hill Publishing Company, 1990

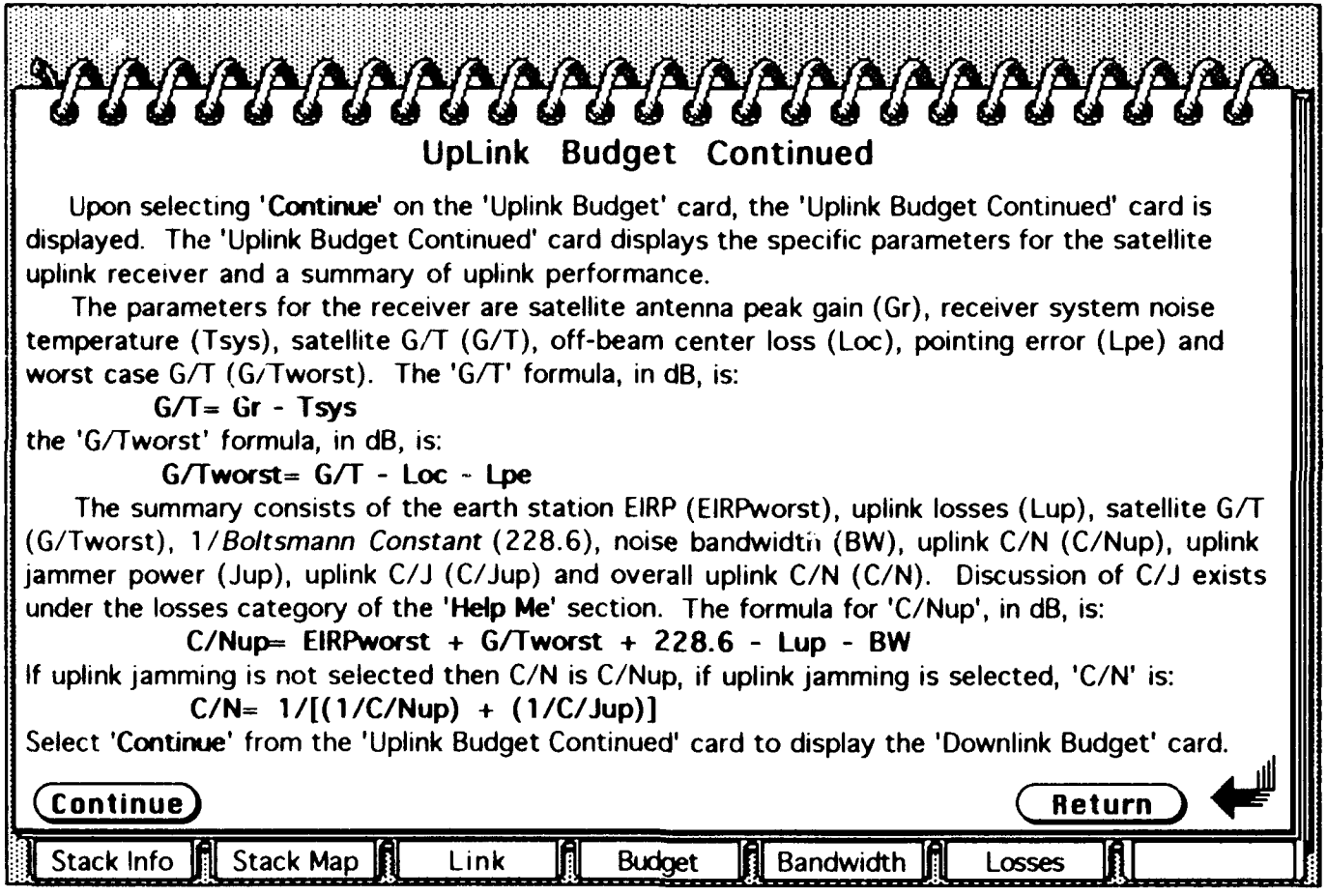
Continue

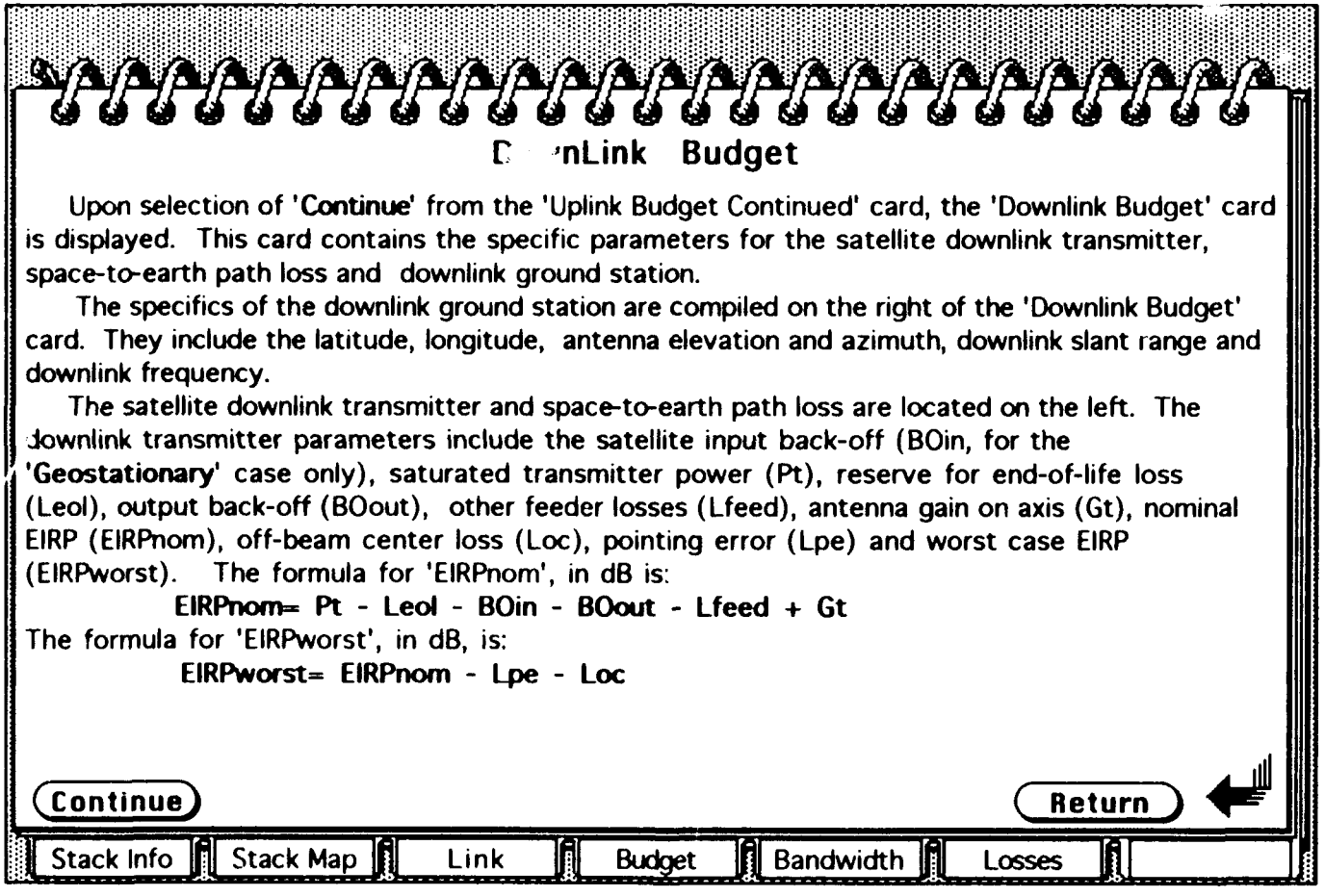
Return

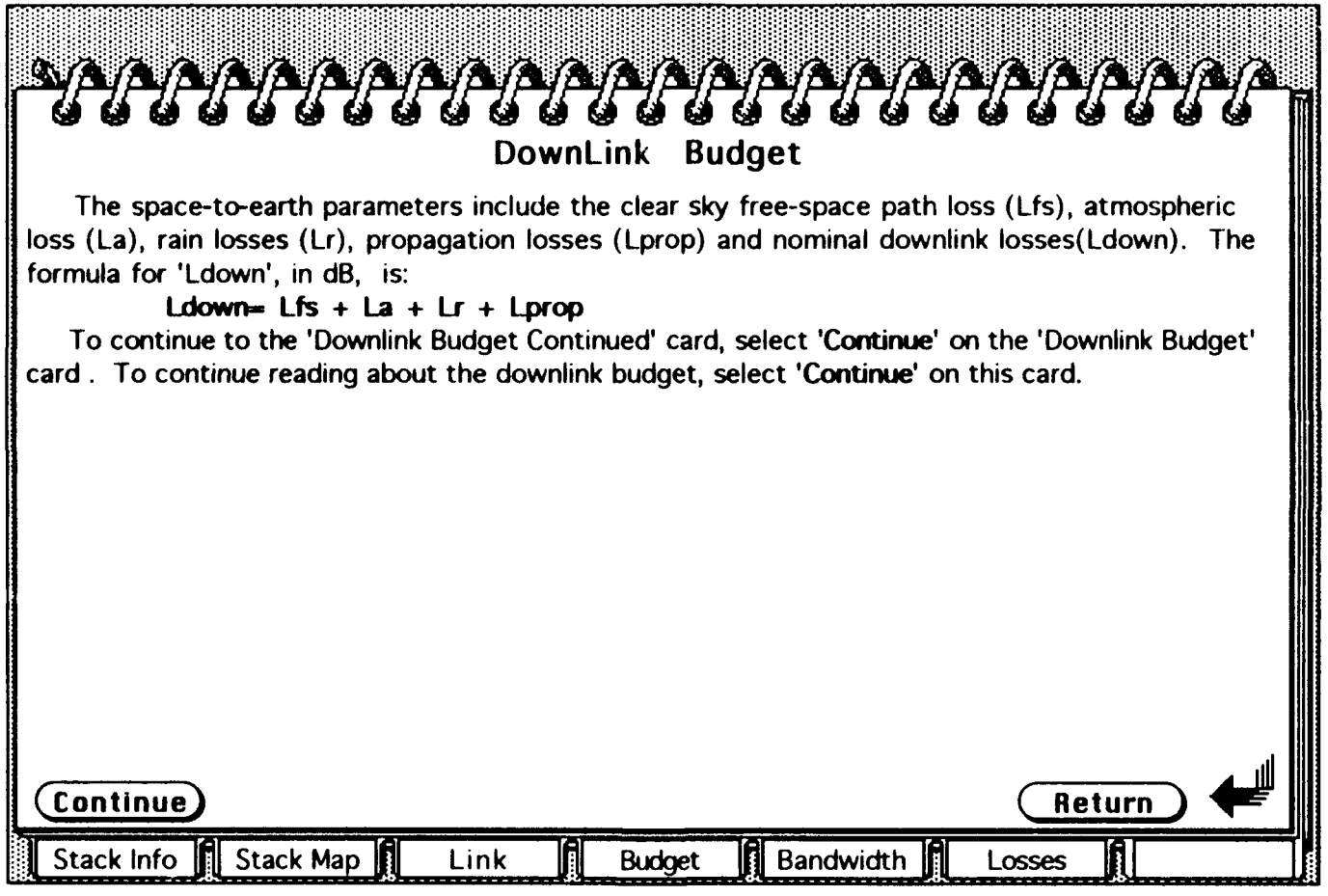
Stack Info | Stack Map | Link | Budget | Bandwidth | Losses


UpLink Budget
The 'Uplink Budget' is the first card displayed upon selection of 'Full Budget' on the 'Ideal Budget' card. This card and the three that follow comprise a detailed analysis of the parameters and performance of the communications system. The calculations are based upon the options selected on the 'Ideal Budget' card.
The specifics of the uplink ground station are compiled on the right of the 'Uplink Budget' card. They include the latitude, longitude, antenna elevation and azimuth, uplink slant range and uplink frequency.
The parameters for the ground station transmitter and earth-to-space path losses are on the left. The ground station parameters include the saturated transmitter power (Pt), reserve for end-of-life loss (Leol), output back-off (BOout), transmission line loss (Ll), other feeder losses (Lfeed), antenna gain on axis (Gt), nominal EIRP (EIRPnom), antenna pointing loss (Lap), antenna loss due to satellite motion (Lm) and worst case EIRP (EIRPworst). The formula for 'EIRPnom', in dB is:
EIRPnom= Pt - Leol - BOout - Ll - Lfeed + Gt
The formula for 'EIRP', in dB is:
EIRPworst= EIRPnom - Lap - Lm
Continue
Return
Stack Info
Stack Map
Link
Budget
Bandwidth
Losses


UpLink Budget
The earth-to-space path loss parameters include the clear sky free-space path loss (Lfs), atmospheric loss (La), rain losses (Lr), propagation losses (Lprop) and nominal uplink losses(Lup). The formula for 'Lup', in dB, is:
Lup= Lfs + La + Lr + Lprop
Units for all displayed information exist on the card. If any of the parameters have not been entered previously, a zero will be entered. This holds true for all of the budget cards.
To continue to the 'Uplink Budget Continued' card, select 'Continue' on the 'Uplink Budget' card . To continue reading about the uplink budget, select 'Continue' on this card.
Continue
Return
Stack Info
Stack Map
Link
Budget
Bandwidth
Losses


UpLink Budget Continued
Upon selecting 'Continue' on the 'Uplink Budget' card, the 'Uplink Budget Continued' card is displayed. The 'Uplink Budget Continued' card displays the specific parameters for the satellite uplink receiver and a summary of uplink performance.
The parameters for the receiver are satellite antenna peak gain (Gr), receiver system noise temperature (Tsys), satellite G/T (G/T), off-beam center loss (Loc), pointing error (Lpe) and worst case G/T (G/Tworst). The 'G/T' formula, in dB, is:
G/T= Gr - Tsys
the 'G/Tworst' formula, in dB, is:
G/Tworst= G/T - Loc - Lpe
The summary consists of the earth station EIRP (EIRPworst), uplink losses (Lup), satellite G/T (G/Tworst), 1/Boltsmann Constant (228.6), noise bandwidth (BW), uplink C/N (C/Nup), uplink jammer power (Jup), uplink C/J (C/Jup) and overall uplink C/N (C/N). Discussion of C/J exists under the losses category of the 'Help Me' section. The formula for 'C/Nup', in dB, is:
C/Nup= EIRPworst + G/Tworst + 228.6 - Lup - BW
If uplink jamming is not selected then C/N is C/Nup, if uplink jamming is selected, 'C/N' is:
C/N= 1/[(1/C/Nup) + (1/C/Jup)]
Select 'Continue' from the 'Uplink Budget Continued' card to display the 'Downlink Budget' card.
Continue
Return
Stack Info
Stack Map
Link
Budget
Bandwidth
Losses


D nLink Budget
Upon selection of 'Continue' from the 'Uplink Budget Continued' card, the 'Downlink Budget' card is displayed. This card contains the specific parameters for the satellite downlink transmitter, space-to-earth path loss and downlink ground station.
The specifics of the downlink ground station are compiled on the right of the 'Downlink Budget' card. They include the latitude, longitude, antenna elevation and azimuth, downlink slant range and downlink frequency.
The satellite downlink transmitter and space-to-earth path loss are located on the left. The downlink transmitter parameters include the satellite input back-off (BOin, for the 'Geostationary' case only), saturated transmitter power (Pt), reserve for end-of-life loss (Leol), output back-off (BOout), other feeder losses (Lfeed), antenna gain on axis (Gt), nominal EIRP (EIRPnom), off-beam center loss (Loc), pointing error (Lpe) and worst case EIRP (EIRPworst). The formula for 'EIRPnom', in dB is:
EIRPnom= Pt - Leol - BOin - BOout - Lfeed + Gt
The formula for 'EIRPworst', in dB, is:
EIRPworst= EIRPnom - Lpe - Loc
Continue
Return
Stack Info
Stack Map
Link
Budget
Bandwidth
Losses


DownLink Budget
The space-to-earth parameters include the clear sky free-space path loss (Lfs), atmospheric loss (La), rain losses (Lr), propagation losses (Lprop) and nominal downlink losses(Ldown). The formula for 'Ldown', in dB, is:
Ldown= Lfs + La + Lr + Lprop
To continue to the 'Downlink Budget Continued' card, select 'Continue' on the 'Downlink Budget' card . To continue reading about the downlink budget, select 'Continue' on this card.
Continue
Return
Stack Info
Stack Map
Link
Budget
Bandwidth
Losses

DownLink Budget Continued

Upon selection of '**Continue**' from the 'Downlink Budget Continued' card, the 'Downlink Budget Continued' card is displayed. The 'Downlink Budget Continued' card displays the specific parameters for the ground station's downlink receiver and a summary of downlink performance. Additionally, for the '**Geostationary**' case, the 'Overall C/N' is displayed

The parameters for the receiver are the increase in sky noise temperature, satellite antenna peak gain (Gr), receiver system noise temperature (Tsys), ground station G/T (G/T), antenna pointing loss (Lap), antenna loss due to satellite motion (Lm), maintenance margin (Lmm) and worst case G/T (G/Tworst). The effects of the increase in sky noise temperature on 'Tsys' are discussed under the 'Rain Losses' category of this section. The 'G/T' formula, in dB, is:

G/T= Gr - Tsys

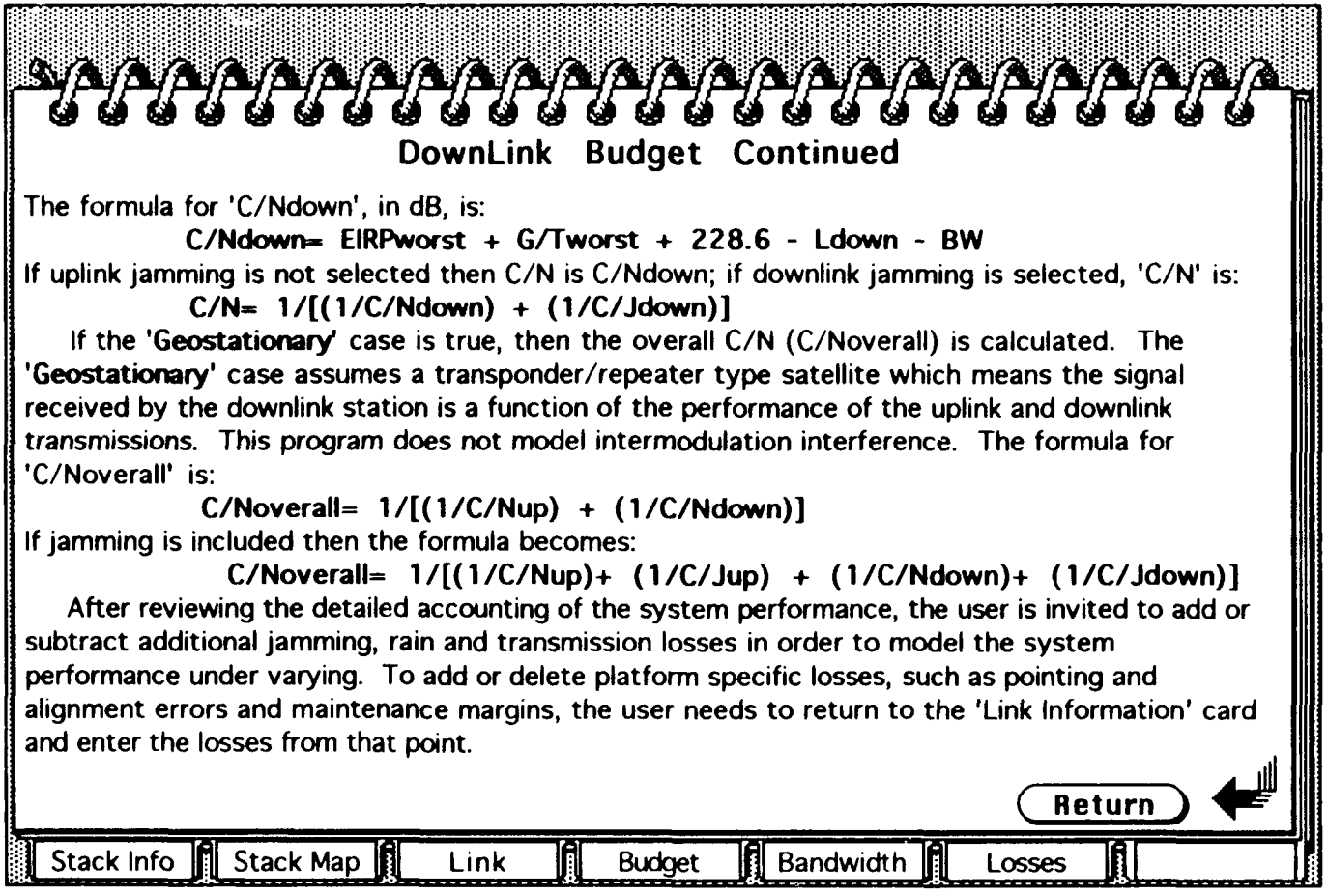
the 'G/Tworst' formula, in dB, is:

G/Tworst= G/T - Lap - Lm - Lmm

The summary consists of the satellite EIRP (EIRPworst), downlink losses (Ldown), ground station G/T (G/Tworst), 1/*Boltsmann Constant* (228.6), noise bandwidth (BW), downlink C/N (C/Ndown), downlink jammer power (Jdown), downlink C/J (C/Jdown) and overall downlink C/N (C/N). Discussion of C/J exists under the losses category of the '**Help Me**' section.

Continue **Return**

Stack Info | Stack Map | Link | Budget | Bandwidth | Losses


DownLink Budget Continued
The formula for 'C/Ndown', in dB, is:
C/Ndown= EIRPworst + G/Tworst + 228.6 - Ldown - BW
If uplink jamming is not selected then C/N is C/Ndown; if downlink jamming is selected, 'C/N' is:
C/N= 1/[(1/C/Ndown) + (1/C/Jdown)]
If the 'Geostationary' case is true, then the overall C/N (C/Noverall) is calculated. The 'Geostationary' case assumes a transponder/repeater type satellite which means the signal received by the downlink station is a function of the performance of the uplink and downlink transmissions. This program does not model intermodulation interference. The formula for 'C/Noverall' is:
C/Noverall= 1/[(1/C/Nup) + (1/C/Ndown)]
If jamming is included then the formula becomes:
C/Noverall= 1/[(1/C/Nup)+ (1/C/Jup) + (1/C/Ndown)+ (1/C/Jdown)]
After reviewing the detailed accounting of the system performance, the user is invited to add or subtract additional jamming, rain and transmission losses in order to model the system performance under varying. To add or delete platform specific losses, such as pointing and alignment errors and maintenance margins, the user needs to return to the 'Link Information' card and enter the losses from that point.
Return
Stack Info
Stack Map
Link
Budget
Bandwidth
Losses

Noise Bandwidth Information

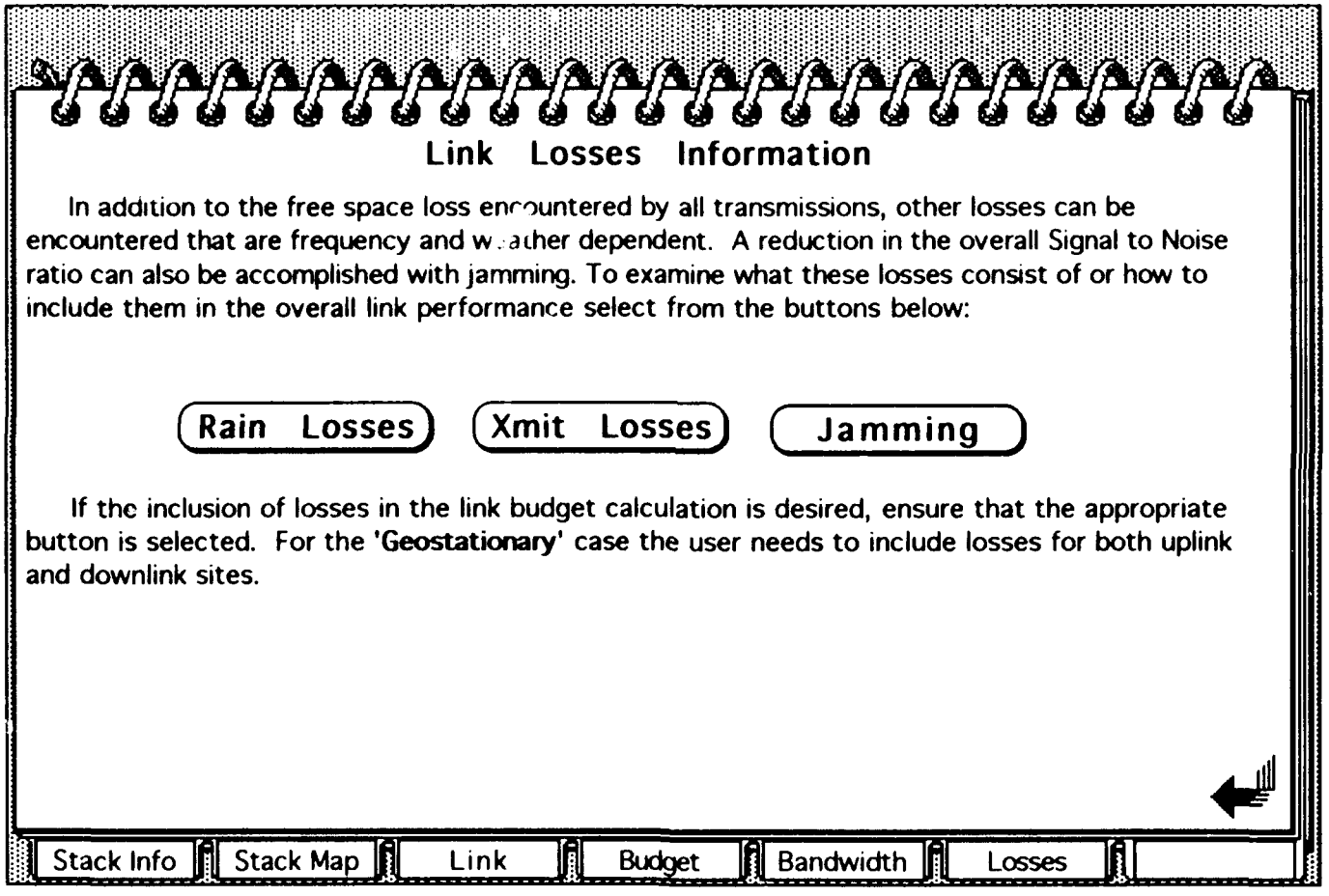
The noise bandwidth (BW) for this program is considered to be the predetection filter (IF) bandwidth. The entry must be made in MHz, i.e. 6,000,000 Hz = 6 MHz. Select '**Noise Bandwidth Unknown**' if this quantity is unavailable. Two entries are now displayed. The first asks for the highest baseband modulation frequency in KHz (B) and the second asks for the peak FM deviation frequency in Hz (d). If the second entry does not apply, enter 0. When the user has completed the entries, select '**Done**'. The program will calculate the noise bandwidth using *Carson's Rule* as shown below:

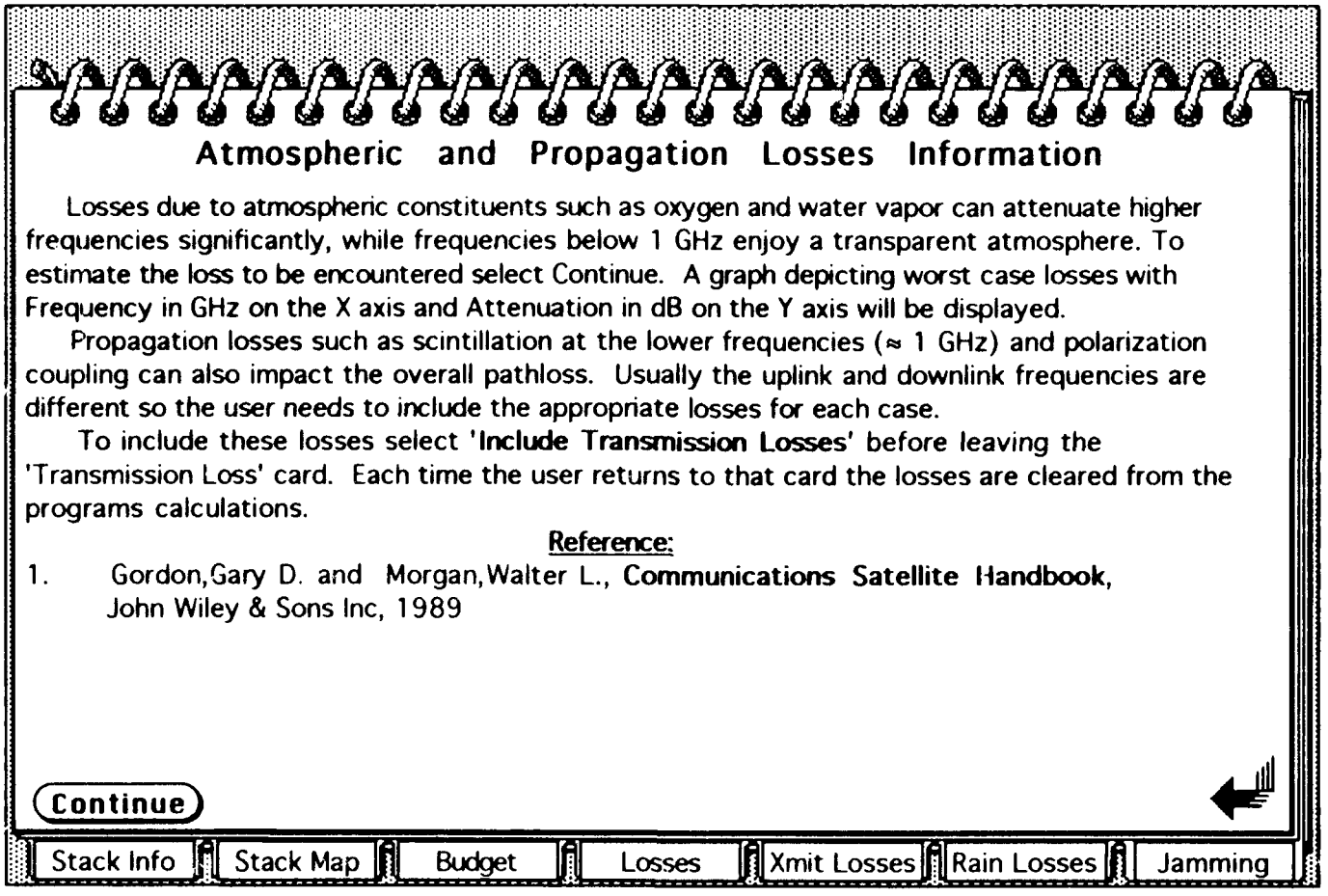
BW=2(B + d)

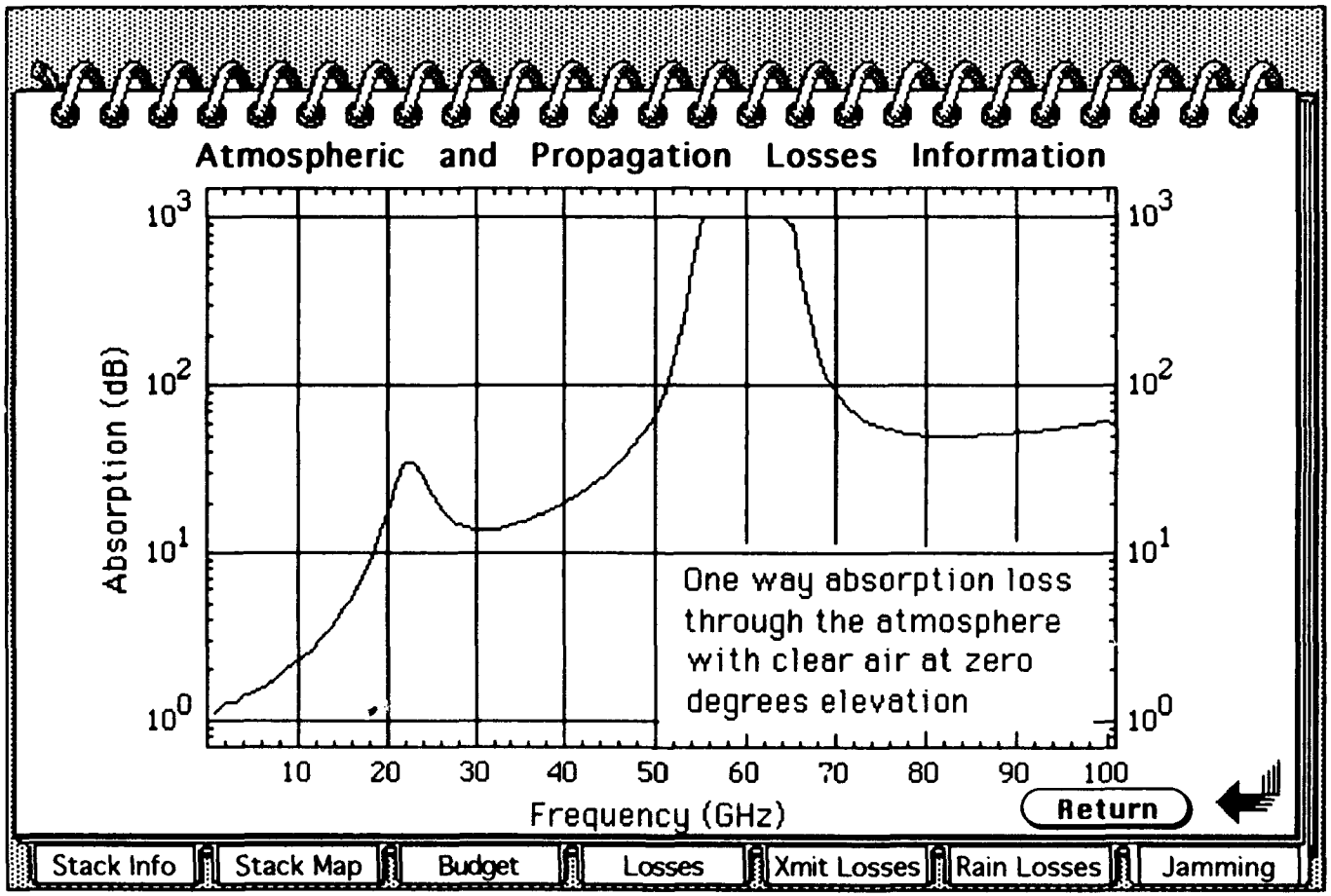
References:

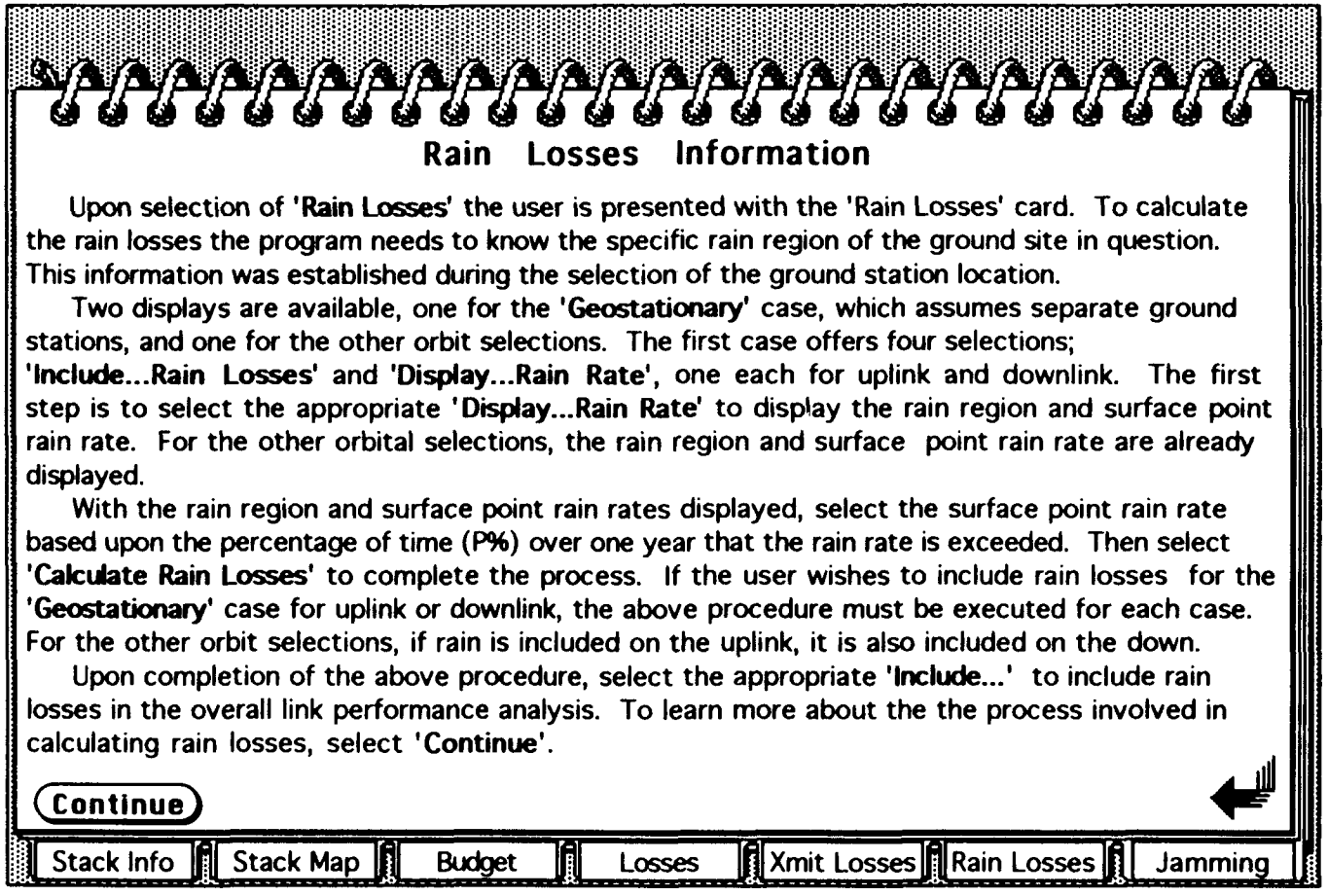
1. Gordon,Gary D. and Morgan,Walter L., **Communications Satellite Handbook**, Page 330, John Wiley & Sons Inc, 1989

2. Ha, TriT., **Digital Satellite Communications, Second Edition**, Page 199, McGraw-Hill Publishing Company, 1990


Link Losses Information
In addition to the free space loss encountered by all transmissions, other losses can be encountered that are frequency and weather dependent. A reduction in the overall Signal to Noise ratio can also be accomplished with jamming. To examine what these losses consist of or how to include them in the overall link performance select from the buttons below:
Rain Losses
Xmit Losses
Jamming
If the inclusion of losses in the link budget calculation is desired, ensure that the appropriate button is selected. For the 'Geostationary' case the user needs to include losses for both uplink and downlink sites.
Stack Info
Stack Map
Link
Budget
Bandwidth
Losses


Atmospheric and Propagation Losses Information
Losses due to atmospheric constituents such as oxygen and water vapor can attenuate higher frequencies significantly, while frequencies below 1 GHz enjoy a transparent atmosphere. To estimate the loss to be encountered select Continue. A graph depicting worst case losses with Frequency in GHz on the X axis and Attenuation in dB on the Y axis will be displayed.
Propagation losses such as scintillation at the lower frequencies (≈ 1 GHz) and polarization coupling can also impact the overall pathloss. Usually the uplink and downlink frequencies are different so the user needs to include the appropriate losses for each case.
To include these losses select 'Include Transmission Losses' before leaving the 'Transmission Loss' card. Each time the user returns to that card the losses are cleared from the programs calculations.
Reference:
1. Gordon,Gary D. and Morgan,Walter L., Communications Satellite Handbook, John Wiley & Sons Inc, 1989
Continue
Stack Info
Stack Map
Budget
Losses
Xmit Losses
Rain Losses
Jamming


Atmospheric and Propagation Losses Information
Absorption (dB)
10^3
10^2
10^1
10^0
10 20 30 40 50 60 70 80 90 100
Frequency (GHz)
One way absorption loss through the atmosphere with clear air at zero degrees elevation
Return
Stack Info
Stack Map
Budget
Losses
Xmit Losses
Rain Losses
Jamming


Rain Losses Information
Upon selection of 'Rain Losses' the user is presented with the 'Rain Losses' card. To calculate the rain losses the program needs to know the specific rain region of the ground site in question. This information was established during the selection of the ground station location.
Two displays are available, one for the 'Geostationary' case, which assumes separate ground stations, and one for the other orbit selections. The first case offers four selections; 'Include...Rain Losses' and 'Display...Rain Rate', one each for uplink and downlink. The first step is to select the appropriate 'Display...Rain Rate' to display the rain region and surface point rain rate. For the other orbital selections, the rain region and surface point rain rate are already displayed.
With the rain region and surface point rain rates displayed, select the surface point rain rate based upon the percentage of time (P%) over one year that the rain rate is exceeded. Then select 'Calculate Rain Losses' to complete the process. If the user wishes to include rain losses for the 'Geostationary' case for uplink or downlink, the above procedure must be executed for each case. For the other orbit selections, if rain is included on the uplink, it is also included on the down.
Upon completion of the above procedure, select the appropriate 'Include...' to include rain losses in the overall link performance analysis. To learn more about the the process involved in calculating rain losses, select 'Continue'.
Continue
Stack Info
Stack Map
Budget
Losses
Xmit Losses
Rain Losses
Jamming

Rain Losses Information

Rain induced attenuation can significantly impact link performance in frequencies above 8.5 GHz. This program uses the *Crane Global Model* to calculate the attenuation. The *Crane Global Model* establishes eight different climate regions on the earth, based upon the amount of annual rainfall and rainfall intensity. The rainfall intensity is established as the surface point rain rate (mm/hr). This program assumes the ground station to be at sea level for these calculations.

The attenuation prediction is a statistical process that is a function of rain rate, percentage of time over one year that the rain rate is exceeded, vertical extent of rain, slant range of the signal through the rain, antenna elevation and frequency. The formula used in the rain loss calculations are as follows:

a= 4.21*10^-5 f^2.42	2.9<=f<=54 GHz
a= 4.09*10^-2 f^0.699	54<=f<=180 GHz
b= 1.41 f^-0.0779	8.5<=f<=25 GHz
b= 2.63 f^-0.272	25<=f<=164 GHz

d= 3.8 - 0.6 ln(Rp)

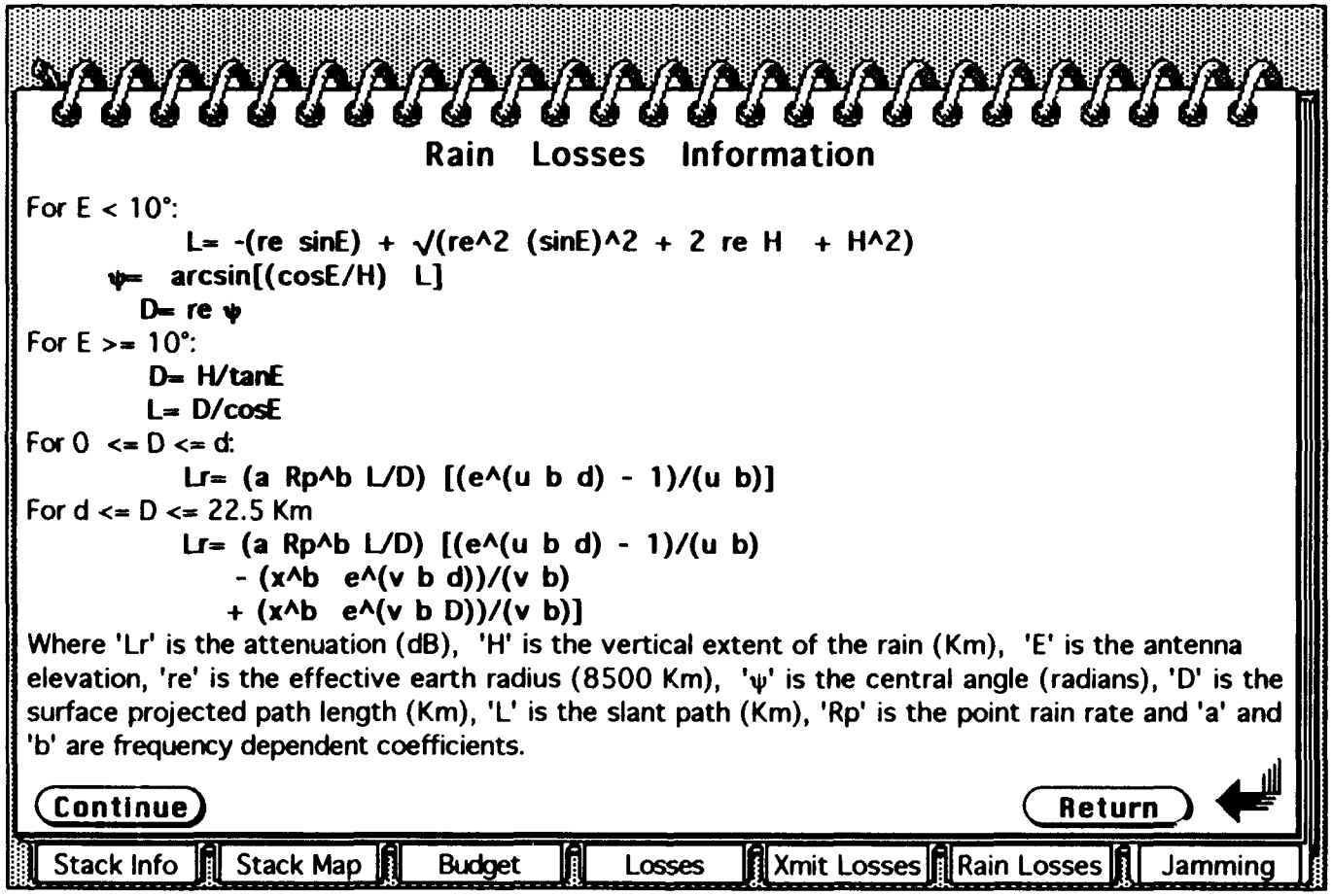
x= 2.3 Rp^-0.17

v= 0.026 - 0.03 ln(Rp)

u= [ln(x e^(v d))]/d

Continue Return

Stack Info | Stack Map | Budget | Losses | Xmit Losses | Rain Losses | Jamming


Rain Losses Information
For E < 10°:
L= -(re sinE) + √(re^2 (sinE)^2 + 2 re H + H^2)
ψ= arcsin[(cosE/H) L]
D= re ψ
For E >= 10°:
D= H/tanE
L= D/cosE
For 0 <= D <= d:
Lr= (a Rp^b L/D) [(e^(u b d) - 1)/(u b)]
For d <= D <= 22.5 Km
Lr= (a Rp^b L/D) [(e^(u b d) - 1)/(u b)
- (x^b e^(v b d))/(v b)
+ (x^b e^(v b D))/(v b)]
Where 'Lr' is the attenuation (dB), 'H' is the vertical extent of the rain (Km), 'E' is the antenna elevation, 're' is the effective earth radius (8500 Km), 'ψ' is the central angle (radians), 'D' is the surface projected path length (Km), 'L' is the slant path (Km), 'Rp' is the point rain rate and 'a' and 'b' are frequency dependent coefficients.
Continue
Return
Stack Info
Stack Map
Budget
Losses
Xmit Losses
Rain Losses
Jamming

Rain Losses Information

In addition to the signal attenuation due to rain, the ground antenna also experiences a rise in noise temperature due to an increase in the sky noise temperature. This change (ΔT) can be added directly to the system noise temperature, if given, and can decrease the downlink G/T. The formula for calculating the 'ΔT' is as follows:

$$\Delta T = 273°K(1 - 1/Lr)$$

References:

1. Gordon,Gary D. and Morgan,Walter L., **Communications Satellite Handbook,** Pages 256 to 261, John Wiley & Sons Inc, 1989

2. Ha, Tri T., **Digital Satellite Communications, Second Edition,** Pages 157 to 156, McGraw-Hill Publishing Company, 1990

Return

Stack Info | Stack Map | Budget | Losses | Xmit Losses | Rain Losses | Jamming

Jamming Information

Upon selection of '**Jamming Losses**' the user is presented with the 'Jamming Losses' card. There are two entries available to the user, 'Jammer Power at the Antenna Port' for the uplink receiver and 'Jammer Power at the Antenna Port' for the downlink receiver. Enter the jammer power at the receiver antenna port (dBW). This entry, realistically, is always less than zero so be certain to include the negative sign (-).

If the jammer power is unknown, select '**Jammer Power Unknown**' . A display offering entry of 'Jammer power output at the jammer' (dBW), and 'Range of the jammer' (Km), will appear. If the unknown is for the uplink, the range entered is the slant range *from* the uplink transmitter to the uplink receiver. If the jammer is in the main beam of the receiver, select '**Jamming in Main Beam**'. If the jammer is just off the beam axis, select '**Jamming at Half Beam**' for a 3 dB reduction in receiver gain. When the entries are made, select '**Done**'. The jammer power at the receiver antenna, in dBW, is calculated with the following formula:

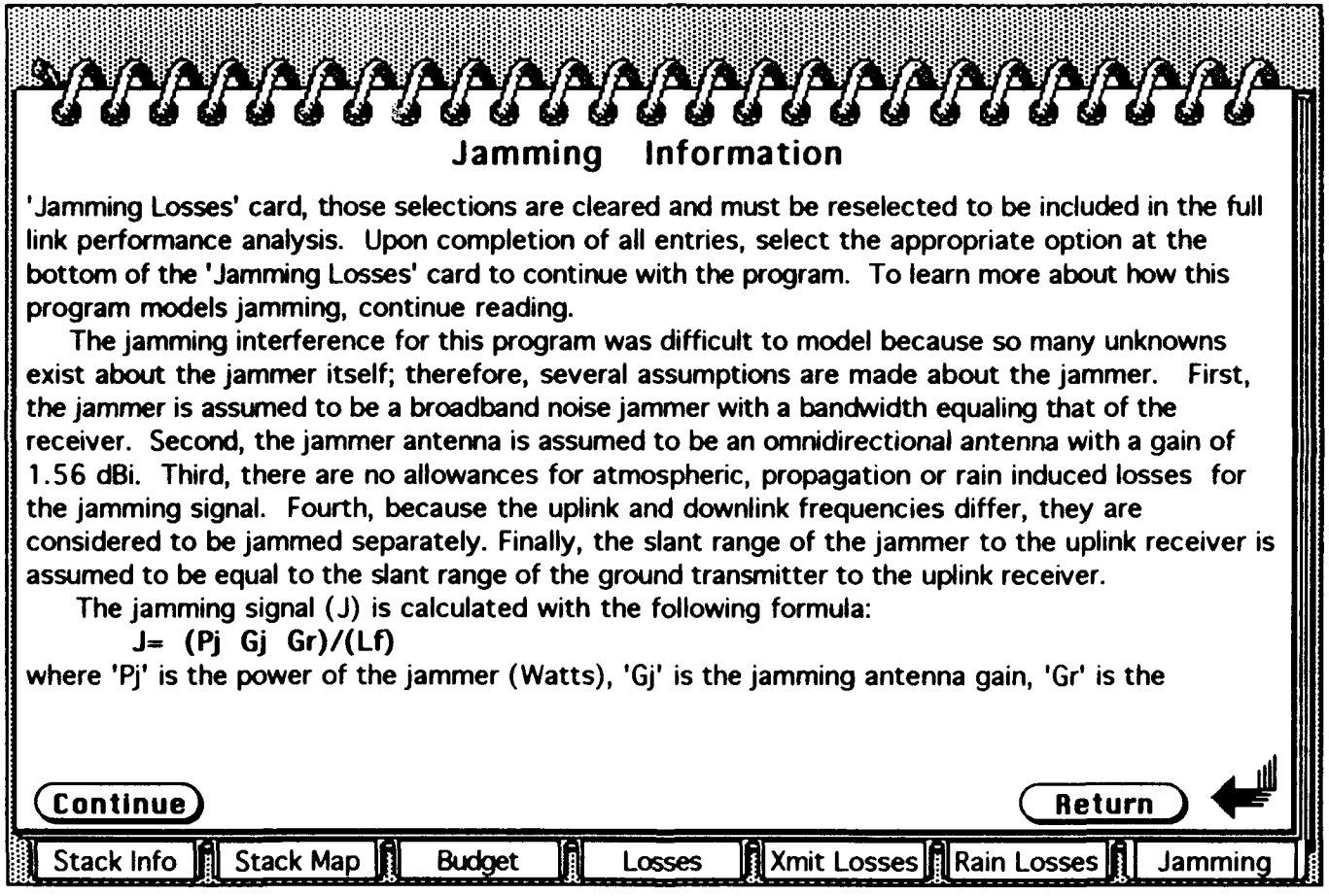
$$P = Pj + Gj + (-3) - Lf$$

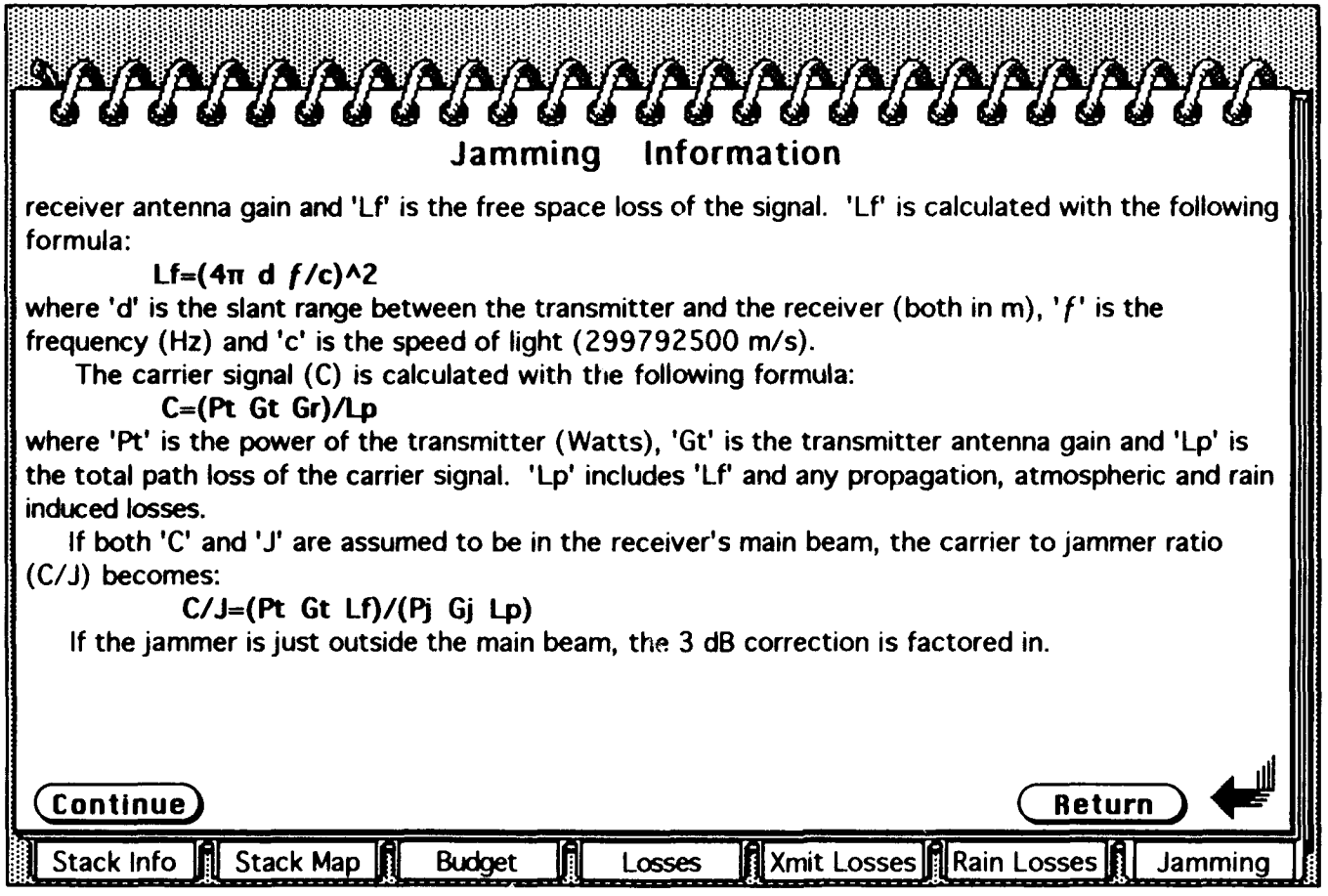
where 'Pj' is the jammer power, 'Gj' is the jammer antenna gain (1.56 dBi), '(-3)' is the 3 dB reduction if selected and Lf is the free space path loss.

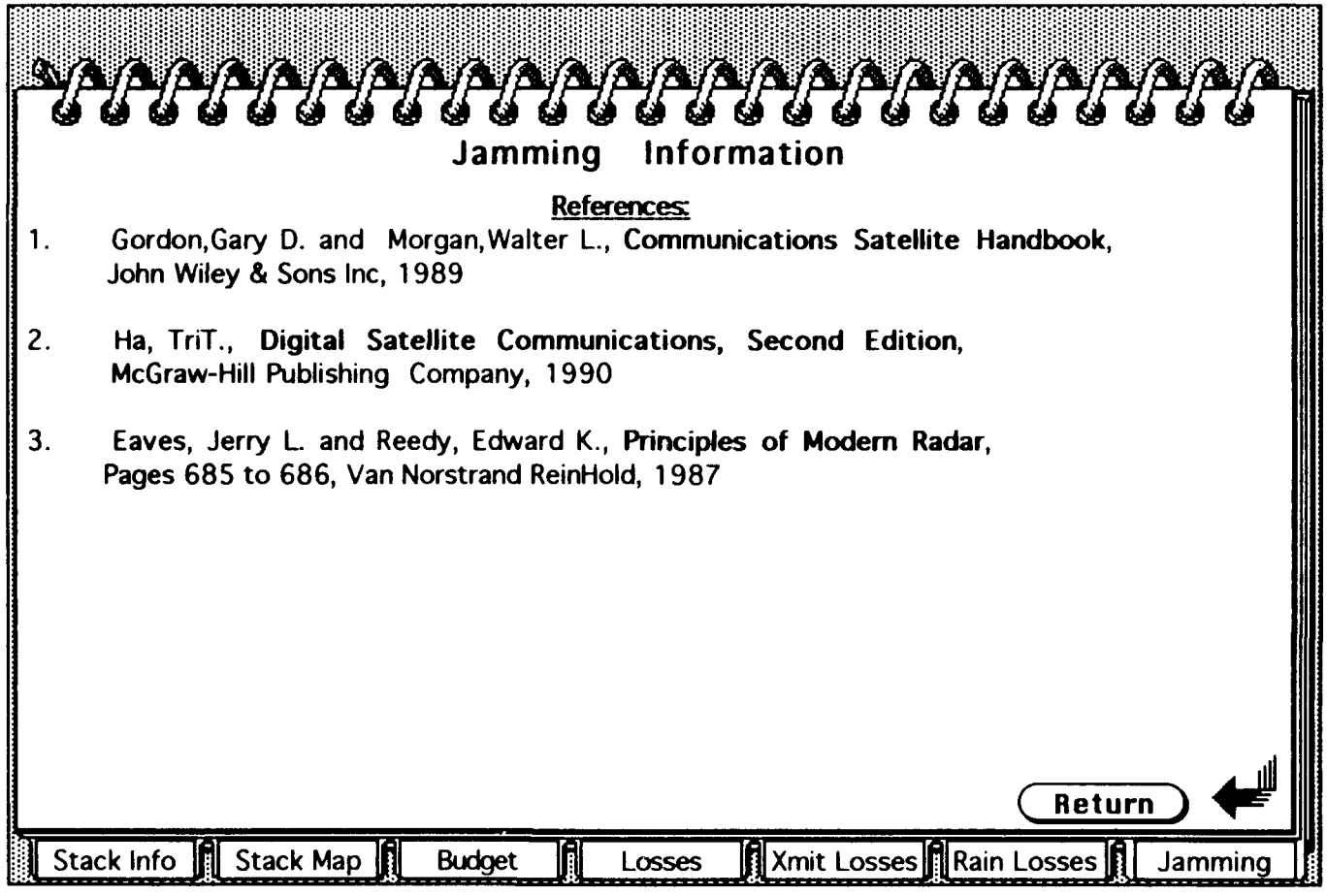
If the user wishes to include jamming losses, be certain to select '**Jam Uplink Receiver**' and/or '**Jam Downlink Receiver**' as appropriate. Each time the user returns to the

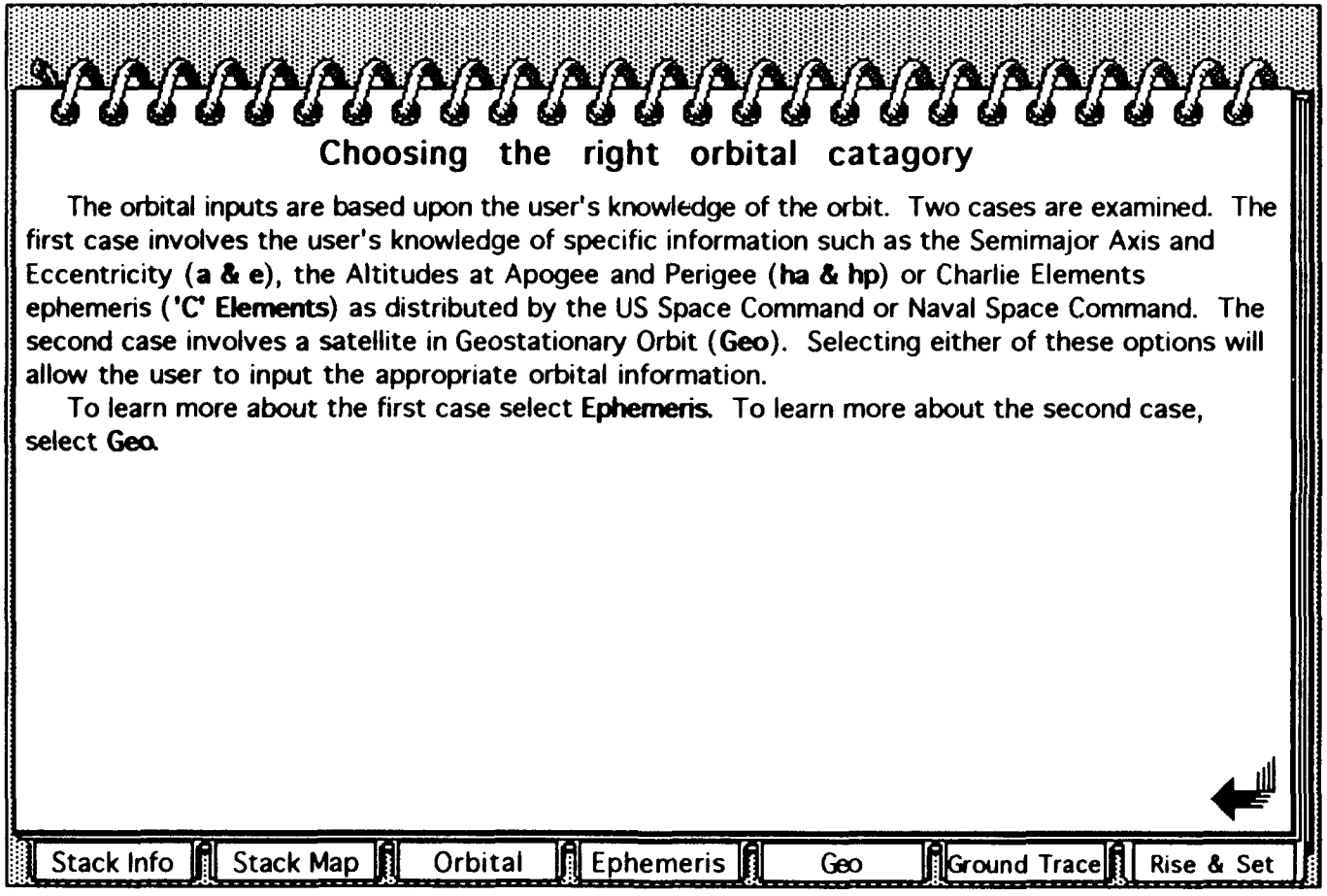
Continue

Stack Info | Stack Map | Budget | Losses | Xmit Losses | Rain Losses | Jamming


Jamming Information
'Jamming Losses' card, those selections are cleared and must be reselected to be included in the full link performance analysis. Upon completion of all entries, select the appropriate option at the bottom of the 'Jamming Losses' card to continue with the program. To learn more about how this program models jamming, continue reading.
The jamming interference for this program was difficult to model because so many unknowns exist about the jammer itself; therefore, several assumptions are made about the jammer. First, the jammer is assumed to be a broadband noise jammer with a bandwidth equaling that of the receiver. Second, the jammer antenna is assumed to be an omnidirectional antenna with a gain of 1.56 dBi. Third, there are no allowances for atmospheric, propagation or rain induced losses for the jamming signal. Fourth, because the uplink and downlink frequencies differ, they are considered to be jammed separately. Finally, the slant range of the jammer to the uplink receiver is assumed to be equal to the slant range of the ground transmitter to the uplink receiver.
The jamming signal (J) is calculated with the following formula:
J= (Pj Gj Gr)/(Lf)
where 'Pj' is the power of the jammer (Watts), 'Gj' is the jamming antenna gain, 'Gr' is the
Continue
Return
Stack Info
Stack Map
Budget
Losses
Xmit Losses
Rain Losses
Jamming

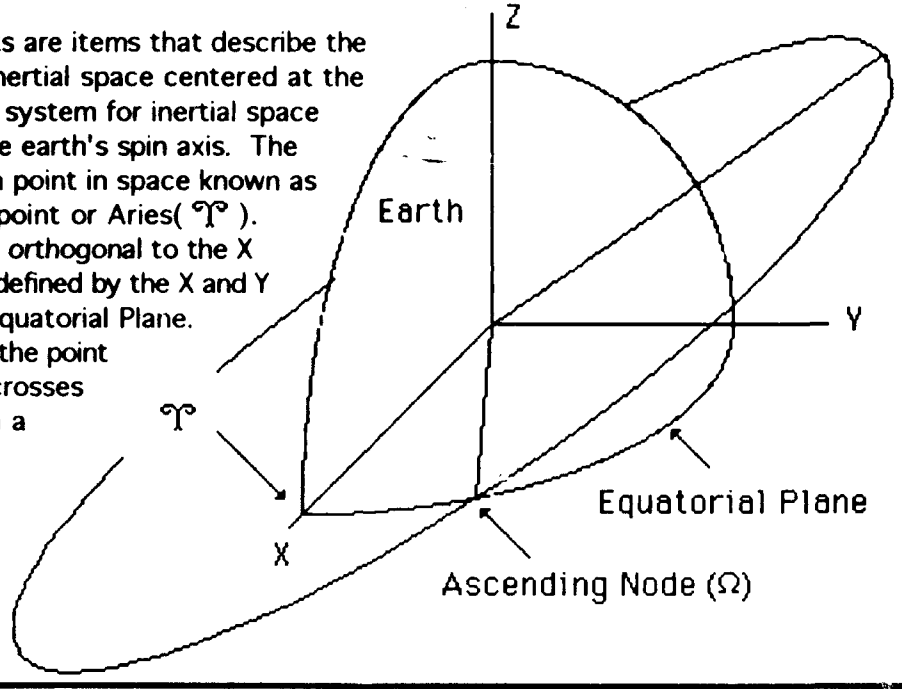

Jamming Information
receiver antenna gain and 'Lf' is the free space loss of the signal. 'Lf' is calculated with the following formula:
Lf=(4π d f/c)^2
where 'd' is the slant range between the transmitter and the receiver (both in m), 'f' is the frequency (Hz) and 'c' is the speed of light (299792500 m/s).
The carrier signal (C) is calculated with the following formula:
C=(Pt Gt Gr)/Lp
where 'Pt' is the power of the transmitter (Watts), 'Gt' is the transmitter antenna gain and 'Lp' is the total path loss of the carrier signal. 'Lp' includes 'Lf' and any propagation, atmospheric and rain induced losses.
If both 'C' and 'J' are assumed to be in the receiver's main beam, the carrier to jammer ratio (C/J) becomes:
C/J=(Pt Gt Lf)/(Pj Gj Lp)
If the jammer is just outside the main beam, the 3 dB correction is factored in.
Continue
Return
Stack Info
Stack Map
Budget
Losses
Xmit Losses
Rain Losses
Jamming


Jamming Information
References:
1. Gordon,Gary D. and Morgan,Walter L., Communications Satellite Handbook, John Wiley & Sons Inc, 1989
2. Ha, TriT., Digital Satellite Communications, Second Edition, McGraw-Hill Publishing Company, 1990
3. Eaves, Jerry L. and Reedy, Edward K., Principles of Modern Radar, Pages 685 to 686, Van Norstrand ReinHold, 1987
Return
Stack Info
Stack Map
Budget
Losses
Xmit Losses
Rain Losses
Jamming


Choosing the right orbital catagory
The orbital inputs are based upon the user's knowledge of the orbit. Two cases are examined. The first case involves the user's knowledge of specific information such as the Semimajor Axis and Eccentricity (a & e), the Altitudes at Apogee and Perigee (ha & hp) or Charlie Elements ephemeris ('C' Elements) as distributed by the US Space Command or Naval Space Command. The second case involves a satellite in Geostationary Orbit (Geo). Selecting either of these options will allow the user to input the appropriate orbital information.
To learn more about the first case select Ephemeris. To learn more about the second case, select Geo.
Stack Info
Stack Map
Orbital
Ephemeris
Geo
Ground Trace
Rise & Set

Orbital Elements

The orbital elements are items that describe the satellite's position in inertial space centered at the earth. The coordinate system for inertial space places the Z axis on the earth's spin axis. The X axis is fixed toward a point in space known as the inertial reference point or Aries(♈). The Y axis is then fixed orthogonal to the X and Z axes. The plane defined by the X and Y axis is known as the Equatorial Plane. The Ascending Node is the point at which the satellite crosses the Equatorial Plane in a positive Z direction.

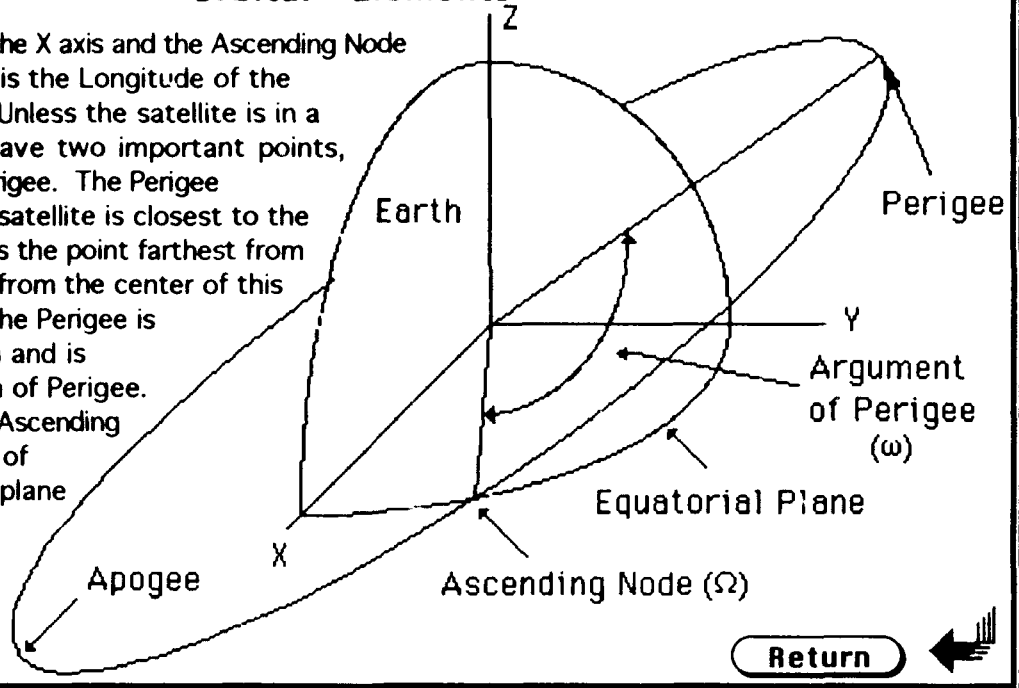


Continue

Stack Info | Stack Map | Orbital | Ephemeris | a & e | Ha & Hp | 'C' Elements

Orbital Elements

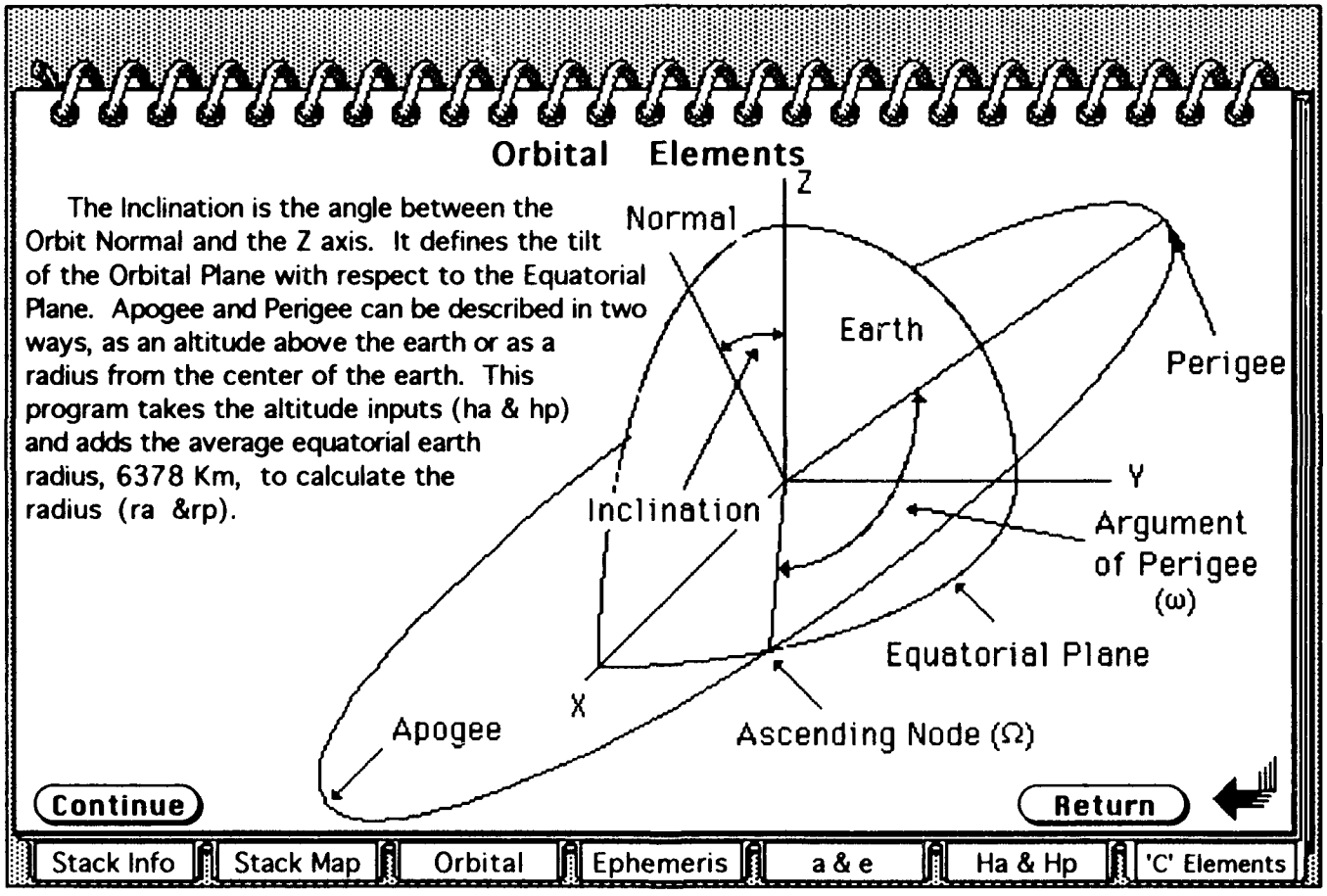
The angle between the X axis and the Ascending Node in the Equatorial Plane is the Longitude of the Ascending Node (Ω). Unless the satellite is in a circular orbit, it will have two important points, the Apogee and the Perigee. The Perigee is the point where the satellite is closest to the earth and the Apogee is the point farthest from the earth. The vector from the center of this coordinate system to the Perigee is fixed for this program and is known as the Direction of Perigee. The angle between the Ascending Node and the Direction of Perigee in the Orbital plane is known as the Argument of Perigee (ω).



Continue

Return

Stack Info | Stack Map | Orbital | Ephemeris | a & e | Ha & Hp | 'C' Elements


Orbital Elements
The Inclination is the angle between the Orbit Normal and the Z axis. It defines the tilt of the Orbital Plane with respect to the Equatorial Plane. Apogee and Perigee can be described in two ways, as an altitude above the earth or as a radius from the center of the earth. This program takes the altitude inputs (ha & hp) and adds the average equatorial earth radius, 6378 Km, to calculate the radius (ra &rp).
Z
Normal
Earth
Perigee
Y
Inclination
Argument of Perigee (ω)
Equatorial Plane
X
Apogee
Ascending Node (Ω)
Continue
Return
Stack Info
Stack Map
Orbital
Ephemeris
a & e
Ha & Hp
'C' Elements

Orbital Elements

A plane view of a typical orbit is shown here. The quantity 'a' is the Semimajor Axis of the orbit. It can be derived from the radius of Apogee and Perigee by the following formula:

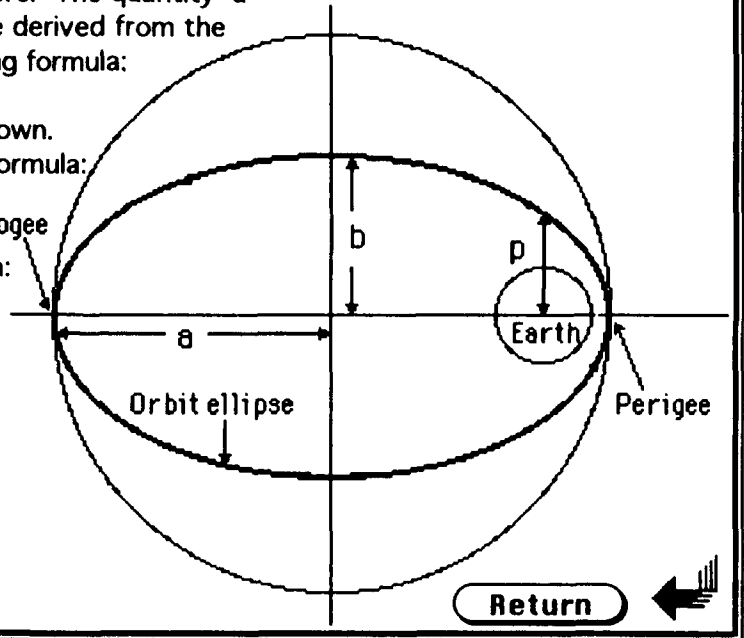
a= (ra + rp)/2

The Semi-Latus Rectum (p) is defined as shown. It is a derived quantity from the following formula:

p=(2 ra rp)/(ra + rp)

The Semiminor Axis (b) is another derived quantity using the following formula:

b=√(ra rp)



Continue

Return

Stack Info | Stack Map | Orbital | Ephemeris | a & e | Ha & Hp | 'C' Elements

Orbital Elements

Another important quantity in the orbit description is the Eccentricity (e). 'e' describes the shape of the orbit. An 'e' of 0 defines a circular orbit and an 'e' up to but not including 1 defines an elliptical orbit. This program is designed to accept only **0 <= e <1**. 'e' can be derived from the following formulas:

e=(ra - rp)/(ra + rp)

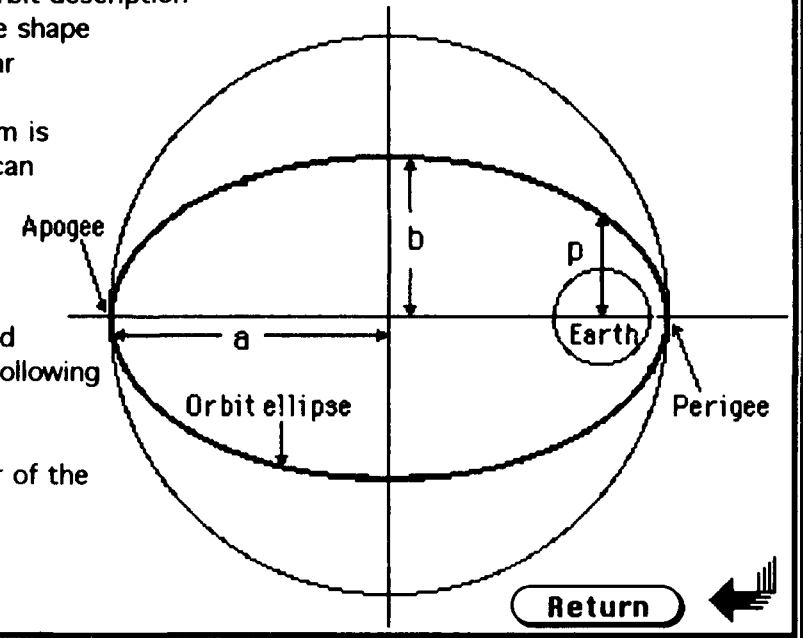
or

e=1 - (rp/a)

The orbital period is the final derived quantity. It can be calculated fron the following formula:

P=2π√(a^3/μ)

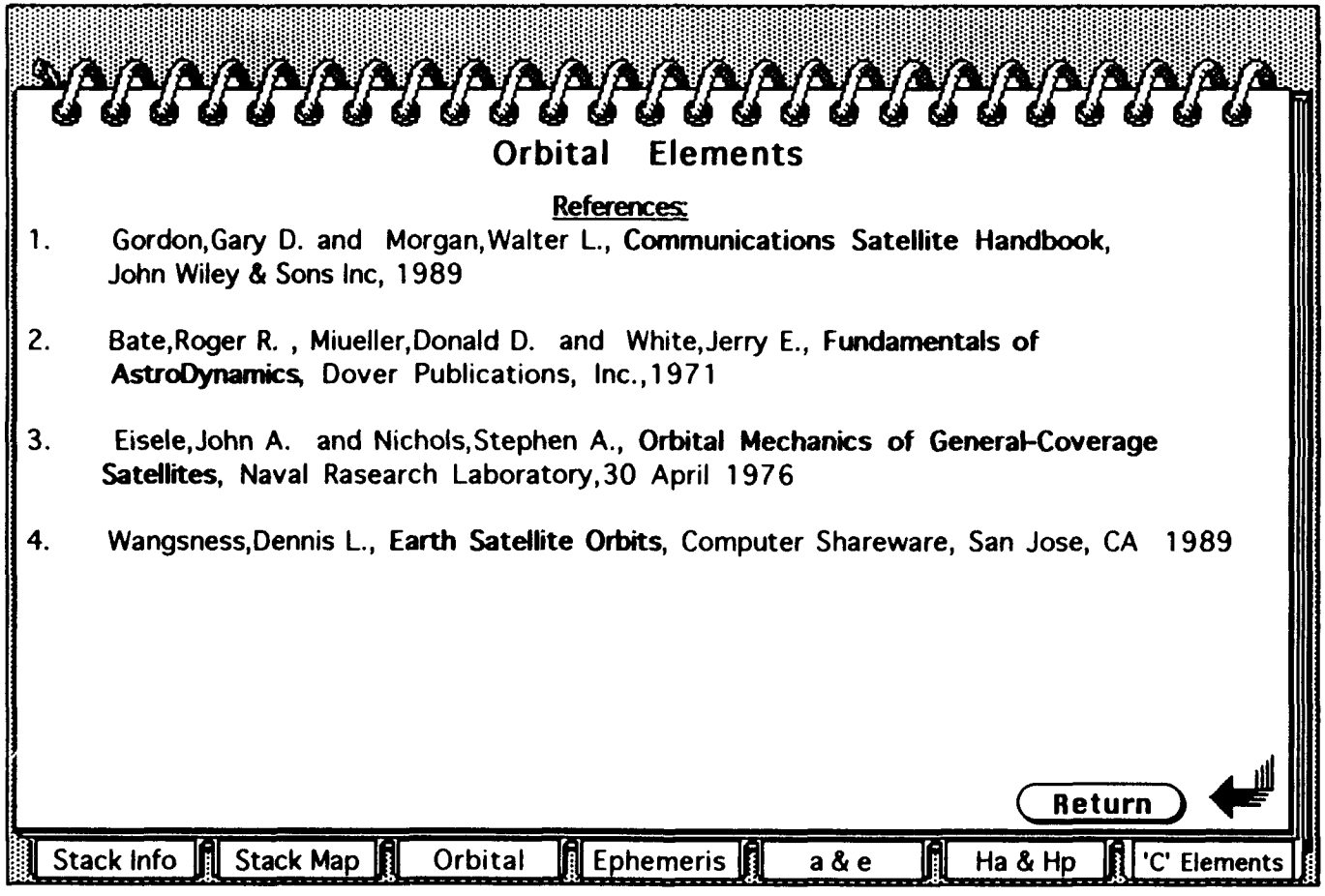
where 'μ' is the Gravitational Parameter of the earth (398600.5 Km^3/sec^2).



Continue

Return

Stack Info | Stack Map | Orbital | Ephemeris | a & e | Ha & Hp | 'C' Elements


Orbital Elements
References:
1. Gordon,Gary D. and Morgan,Walter L., Communications Satellite Handbook, John Wiley & Sons Inc, 1989
2. Bate,Roger R. , Miueller,Donald D. and White,Jerry E., Fundamentals of AstroDynamics, Dover Publications, Inc.,1971
3. Eisele,John A. and Nichols,Stephen A., Orbital Mechanics of General-Coverage Satellites, Naval Rasearch Laboratory,30 April 1976
4. Wangsness,Dennis L., Earth Satellite Orbits, Computer Shareware, San Jose, CA 1989
Return
Stack Info
Stack Map
Orbital
Ephemeris
a & e
Ha & Hp
'C' Elements

Semimajor Axis and Eccentricity Known

If the Semimajor Axis (a) and Eccentricity (e, 0 up to 1) are known, enter 'a' (Km). 'a' cannot be less than the earth's average equatorial radius of **6378 Km**. Enter 'e' and ensure that e is a quantity **0<= e <1**. Additionally the Inclination (i), Argument of Perigee (ω) and Longitude of the Ascending Node (Ω) are required. Enter those quantities as decimal degrees. Limits for those quantities are as follows:

i : 0° <= i <= 180°
ω: 0° <= ω <= 360°
Ω: 0° <= Ω <= 360°

If the orbit is circular (e = 0) then any entry for 'ω' will do.

Select **'Orbital Elements'** to display the entered and derived ephemeris. If the orbit described is not the orbit desired, Select **'Orbital Info'** to re-enter the information. If the ephemeris appears correct then select **'Ground Station'** to enter the Ground Station Information.



Stack Info | Stack Map | Orbital | Ephemeris | a & e | Ha & Hp | 'C' Elements

Altitudes of Apogee and Perigee Known

If the Altitudes of Perigee (hp) and Apogee (ha) are known, enter them in kilometers. Additionally the Inclination (i), Argument of Perigee (ω) and Longitude of the Ascending Node (Ω) are required. Enter those quantities as decimal degrees. Limits for those quantities are as follows:

i : $0^\circ \leq i \leq 180^\circ$

ω: $0^\circ \leq \omega \leq 360^\circ$

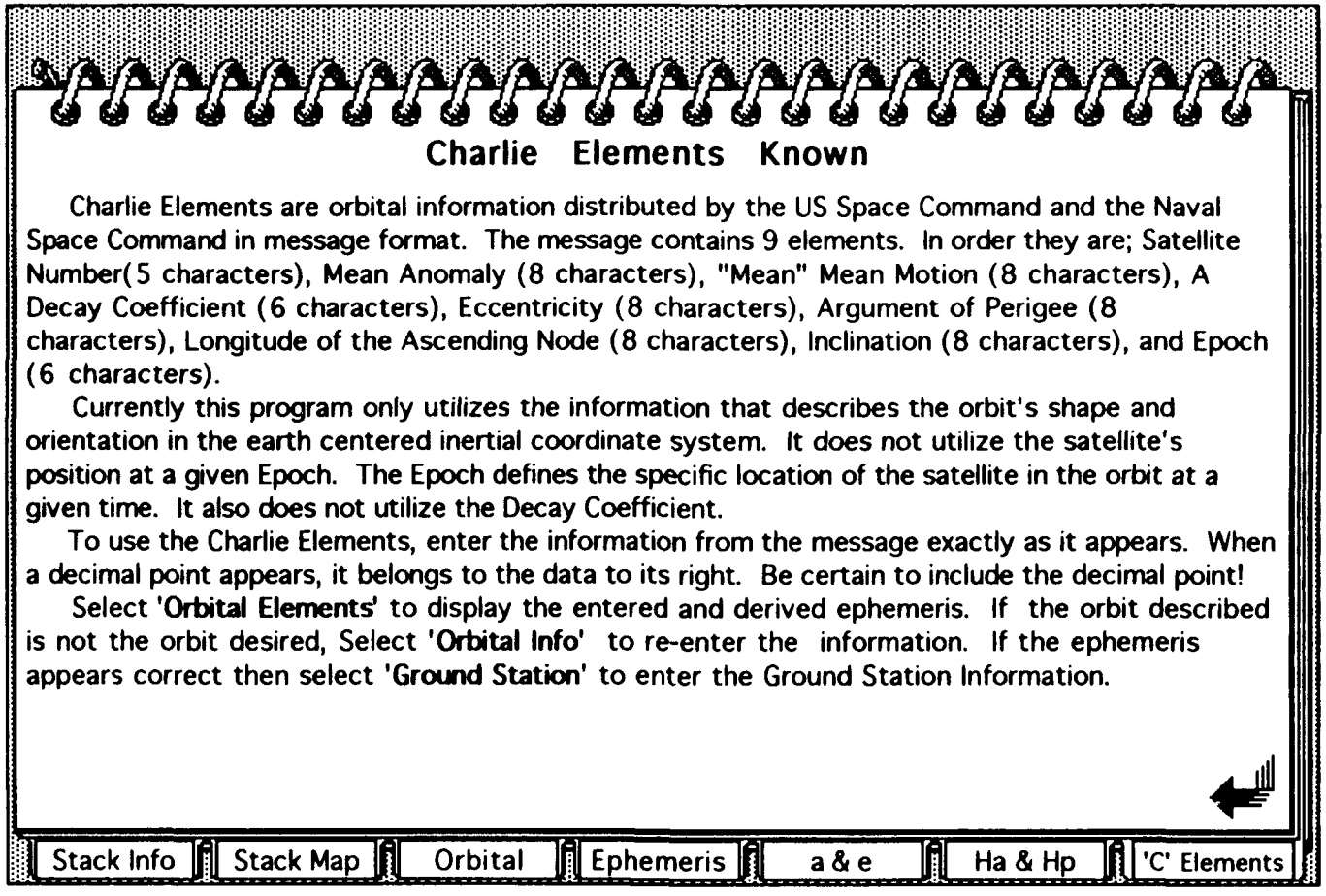
Ω: $0^\circ \leq \Omega \leq 360^\circ$

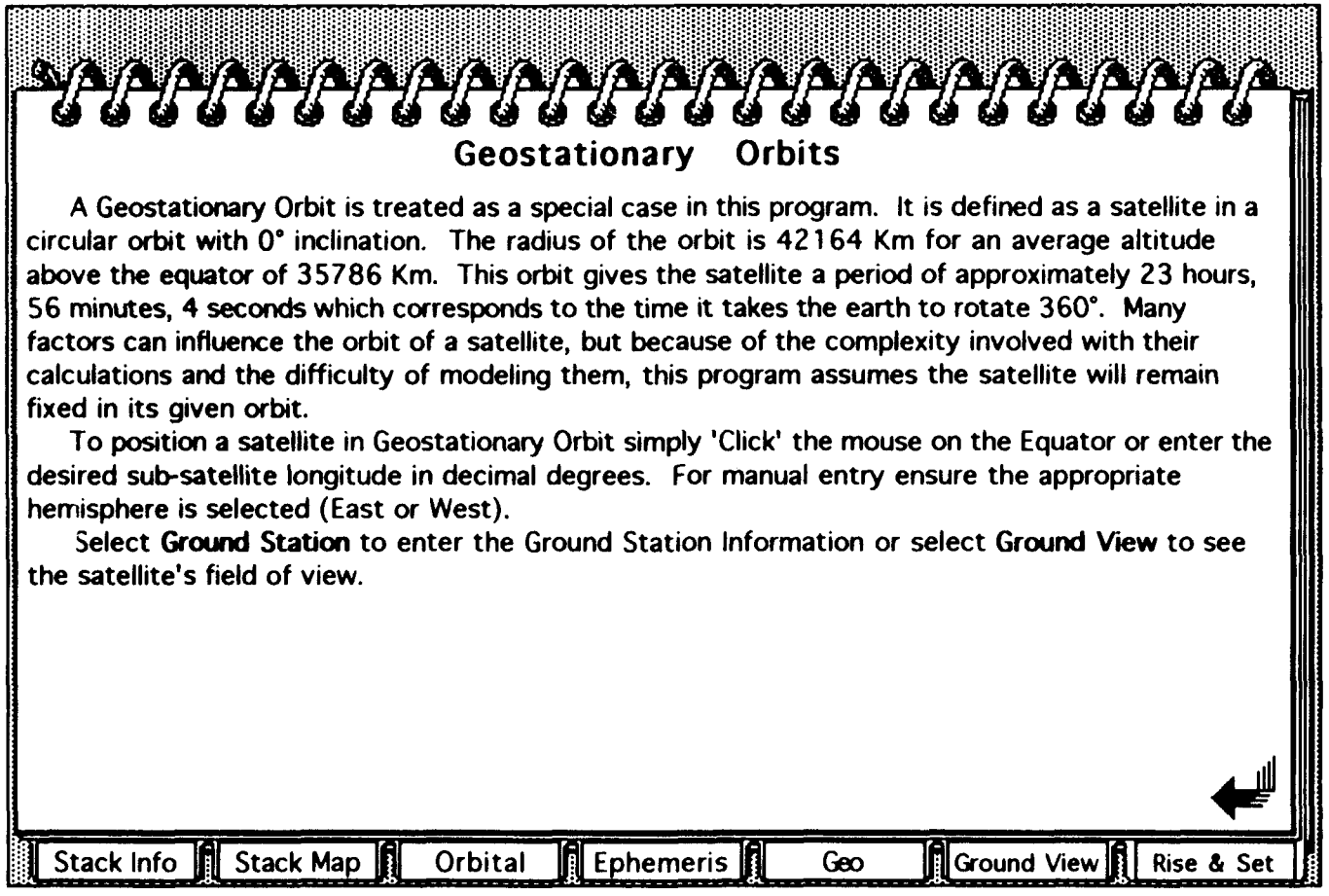
If the orbit is circular (ha = hp) then any entry for 'ω' will do.

Select '**Orbital Elements**' to display the entered and derived ephemeris. If the orbit described is not the orbit desired, Select '**Orbital Info**' to re-enter the information. If the ephemeris appears correct then select '**Ground Station**' to enter the Ground Station Information.



Stack Info | Stack Map | Orbital | Ephemeris | a & e | Ha & Hp | 'C' Elements


Charlie Elements Known
Charlie Elements are orbital information distributed by the US Space Command and the Naval Space Command in message format. The message contains 9 elements. In order they are; Satellite Number(5 characters), Mean Anomaly (8 characters), "Mean" Mean Motion (8 characters), A Decay Coefficient (6 characters), Eccentricity (8 characters), Argument of Perigee (8 characters), Longitude of the Ascending Node (8 characters), Inclination (8 characters), and Epoch (6 characters).
Currently this program only utilizes the information that describes the orbit's shape and orientation in the earth centered inertial coordinate system. It does not utilize the satellite's position at a given Epoch. The Epoch defines the specific location of the satellite in the orbit at a given time. It also does not utilize the Decay Coefficient.
To use the Charlie Elements, enter the information from the message exactly as it appears. When a decimal point appears, it belongs to the data to its right. Be certain to include the decimal point!
Select 'Orbital Elements' to display the entered and derived ephemeris. If the orbit described is not the orbit desired, Select 'Orbital Info' to re-enter the information. If the ephemeris appears correct then select 'Ground Station' to enter the Ground Station Information.
Stack Info
Stack Map
Orbital
Ephemeris
a & e
Ha & Hp
'C' Elements


Geostationary Orbits
A Geostationary Orbit is treated as a special case in this program. It is defined as a satellite in a circular orbit with 0° inclination. The radius of the orbit is 42164 Km for an average altitude above the equator of 35786 Km. This orbit gives the satellite a period of approximately 23 hours, 56 minutes, 4 seconds which corresponds to the time it takes the earth to rotate 360°. Many factors can influence the orbit of a satellite, but because of the complexity involved with their calculations and the difficulty of modeling them, this program assumes the satellite will remain fixed in its given orbit.
To position a satellite in Geostationary Orbit simply 'Click' the mouse on the Equator or enter the desired sub-satellite longitude in decimal degrees. For manual entry ensure the appropriate hemisphere is selected (East or West).
Select Ground Station to enter the Ground Station Information or select Ground View to see the satellite's field of view.
Stack Info
Stack Map
Orbital
Ephemeris
Geo
Ground View
Rise & Set

Ground View



The 'Ground View' selection displays a global map to the user with an icon of a satellite at the longitude selected for its geostationary position. The icons for the uplink  and downlink  station reside over their respective geographic locations. A footprint of the satellite's field of view is drawn based upon the largest minimum antenna elevation of the ground sites. If the ground station does not appear to be in view of the satellite by the footprint, it may still be in view if its minimum antenna elevation is less than the other ground sites. An alert will appear to the user if either or both ground sites are out of the view of the satellite. The user will be required to place both ground sites in view of the satellite in order to utilize the 'Link Info' portion of this program.

Displayed for the user's information are the respective antenna elevations and and compass azimuth from the ground station to the satellite. This program accounts for the oblateness of the earth when calculating actual antenna elevations. For more dicussion on this topic, select **'Rise and Set'**. The formula for calculating the azimuth angle (A) is as follows:

$$A = \arctan[\sin\Delta\lambda / (\cos\phi \tan\partial - \sin\phi \cos\Delta\lambda)]$$

where '$\Delta\lambda$' is the difference in the satellite's and ground station's longitude (°), 'ϕ' is the earth station's latitude (°) and '∂' is the sub-satellite points latitude.

Continue



Stack Info | Stack Map | Orbital | Ephemeris | Geo | Ground View | Rise & Set

Ground View

The formula for the true antenna elevation (h) is as follows:

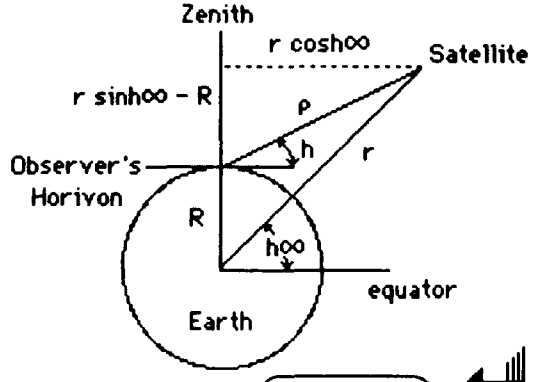
$$h = \arctan[(\sinh_\infty - R/r)/\cosh_\infty]$$

where 'R' is the radius of the earth corrected for oblateness (Km), 'r' is the radius of the satellite (42164 Km for a geostationary satellite) and 'h_∞' is the satellite's elevation above the equator. 'h_∞' is calculated with the following formula:

$$h_\infty = \arcsin[\sin\partial \sin\phi + \cos\partial \cos\phi \cos\Delta\lambda]$$

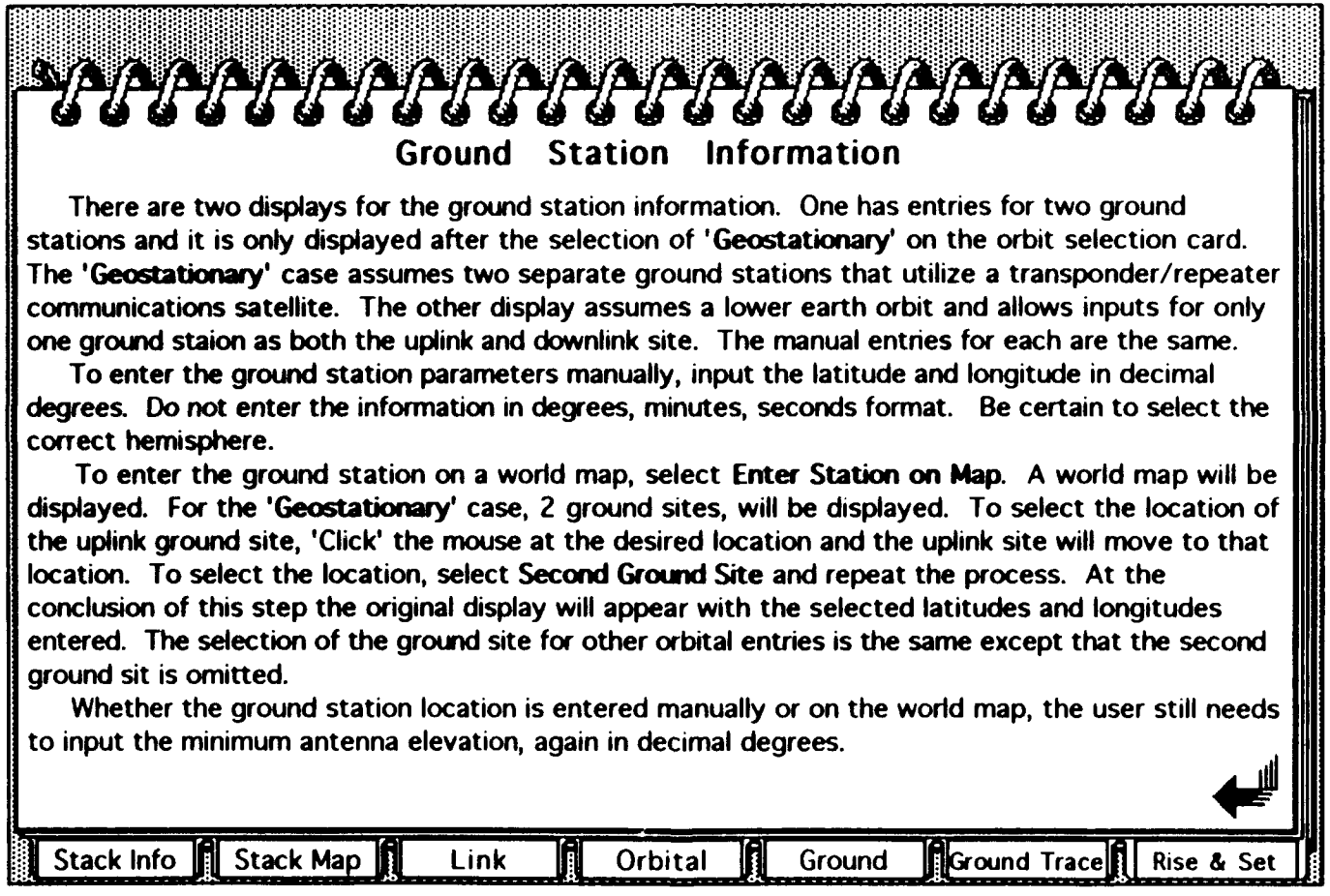
Reference:

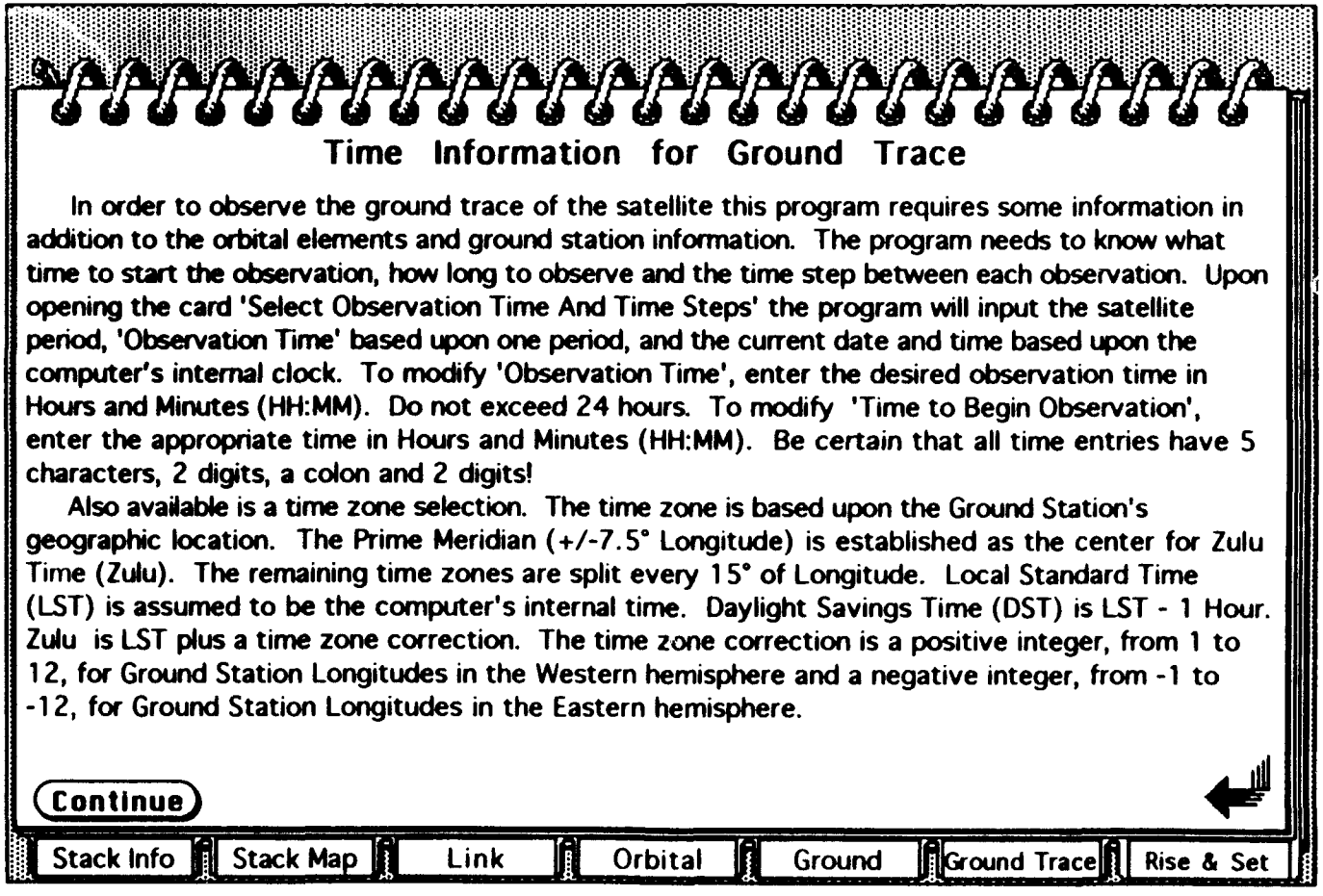
1. Gordon,Gary D. and Morgan,Walter L., **Communications Satellite Handbook,** Pages 825 to 827, John Wiley & Sons Inc, 1989

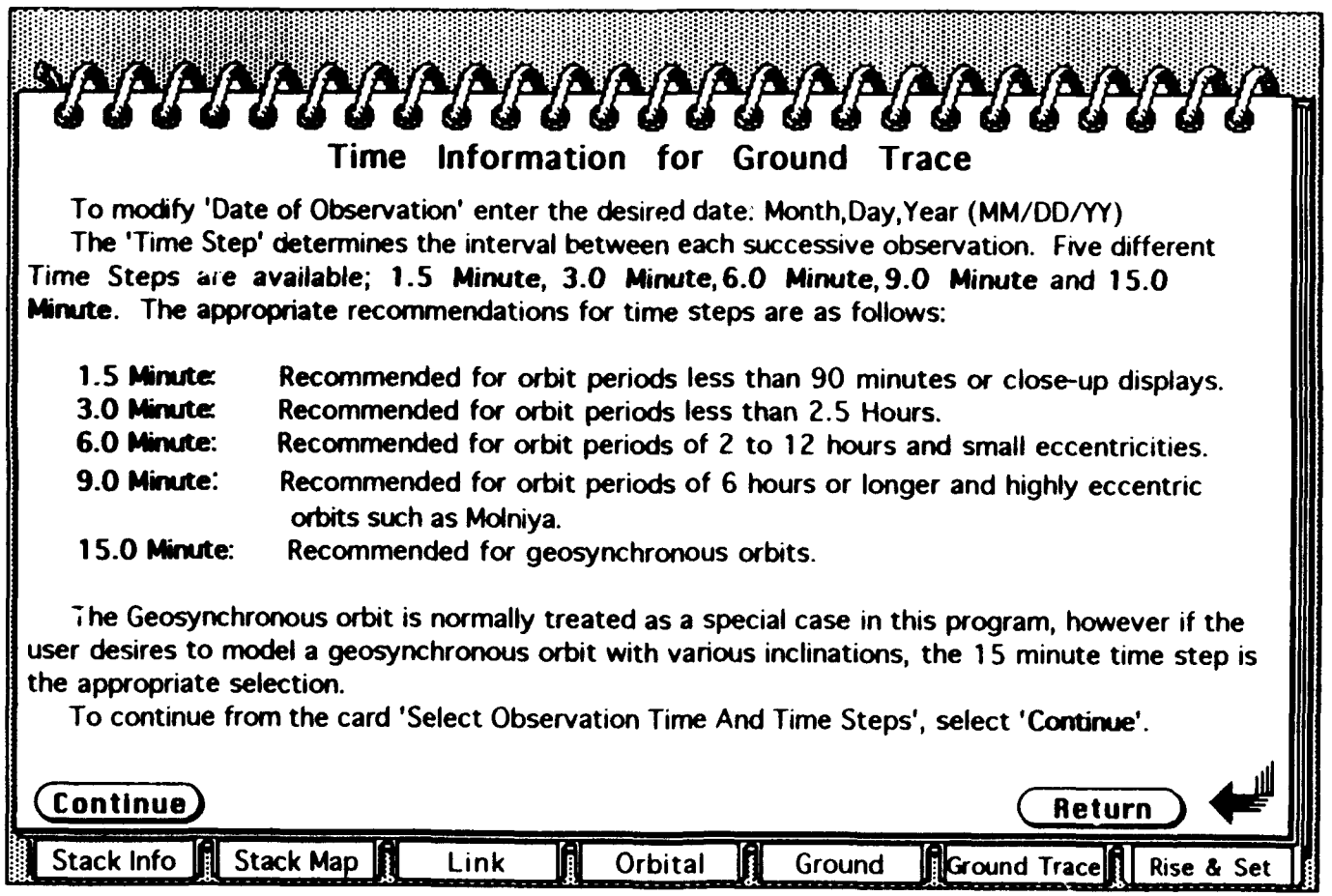


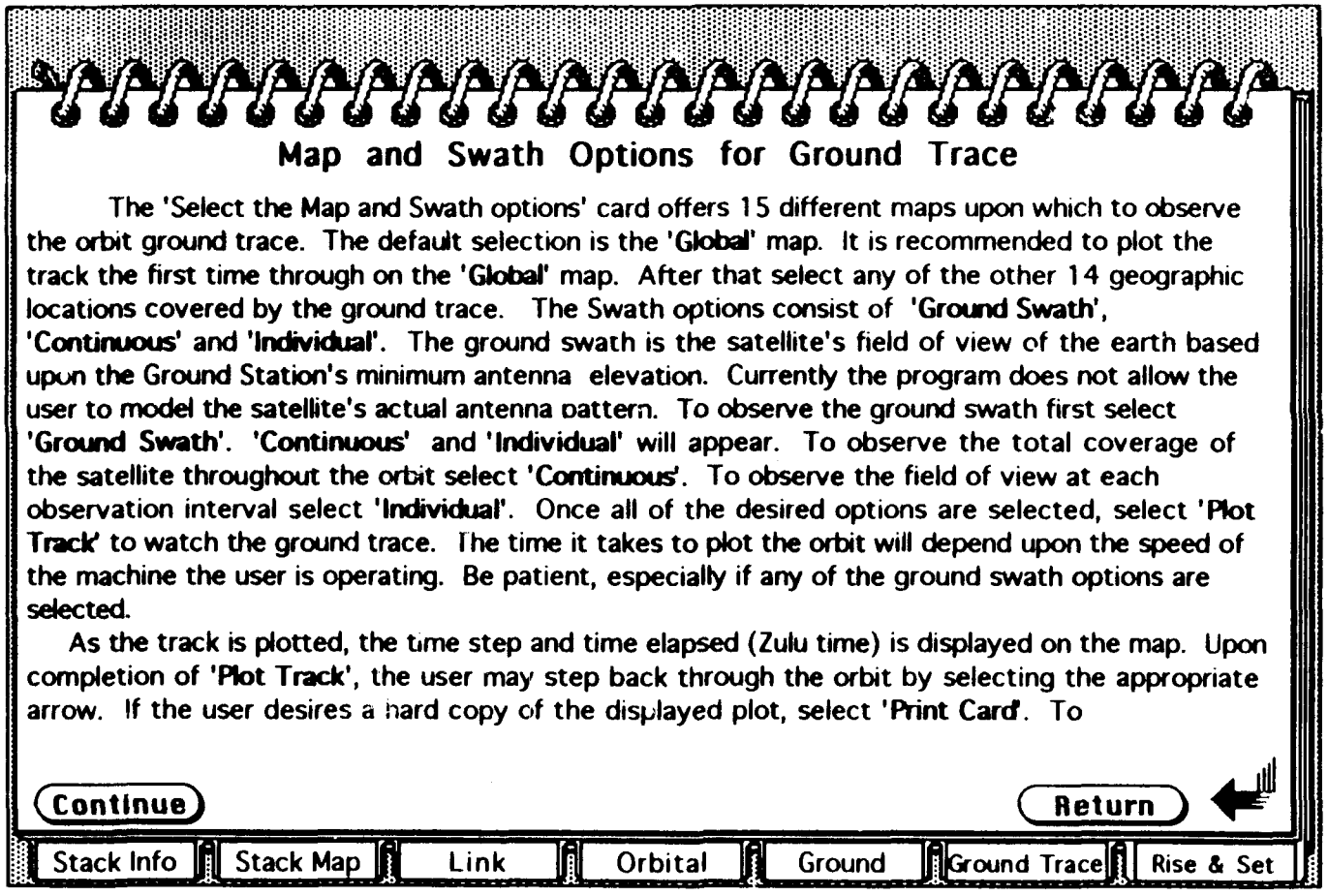
Return

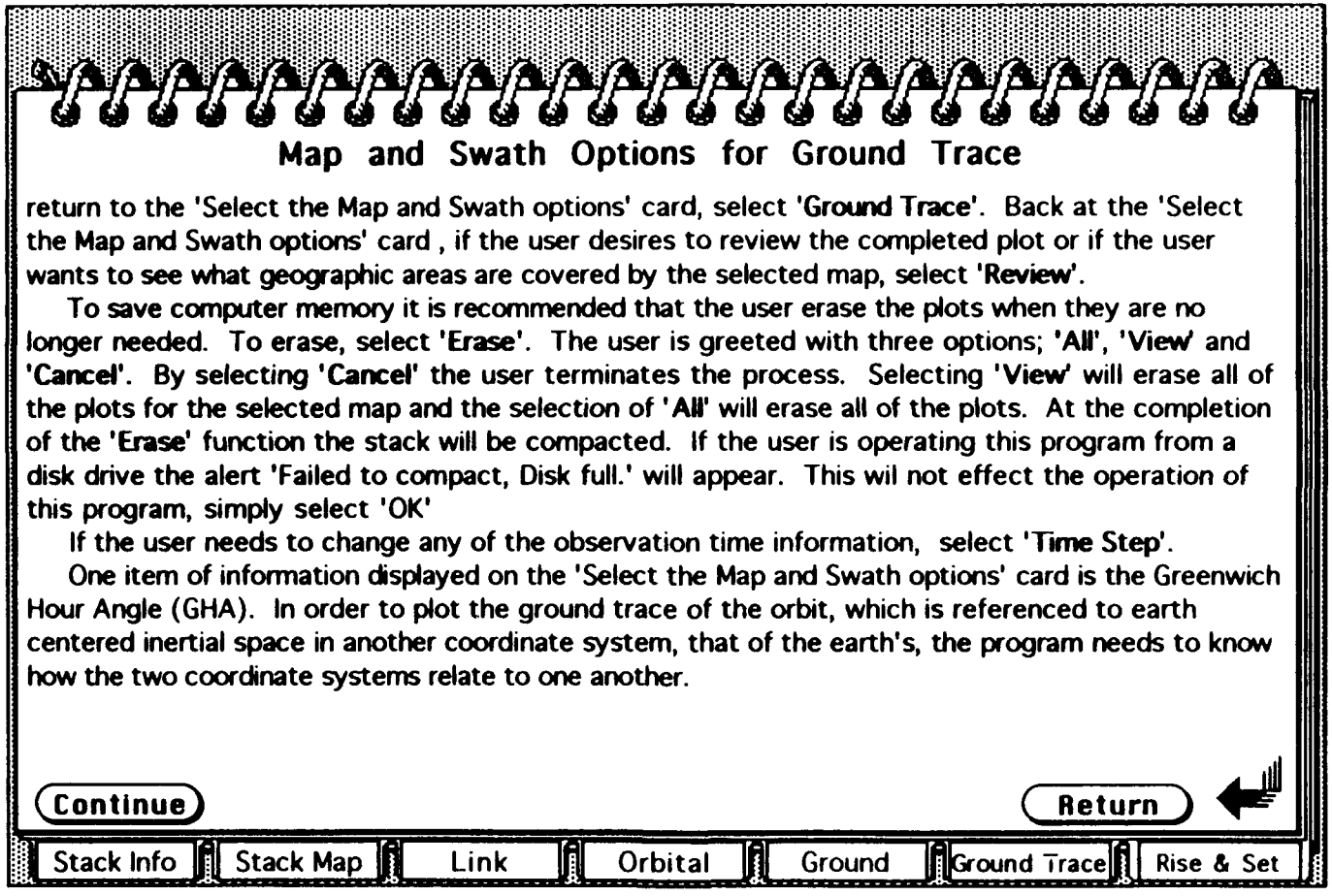
Stack Info | Stack Map | Orbital | Ephemeris | Geo | Ground View | Rise & Set


Ground Station Information
There are two displays for the ground station information. One has entries for two ground stations and it is only displayed after the selection of 'Geostationary' on the orbit selection card. The 'Geostationary' case assumes two separate ground stations that utilize a transponder/repeater communications satellite. The other display assumes a lower earth orbit and allows inputs for only one ground staion as both the uplink and downlink site. The manual entries for each are the same.
To enter the ground station parameters manually, input the latitude and longitude in decimal degrees. Do not enter the information in degrees, minutes, seconds format. Be certain to select the correct hemisphere.
To enter the ground station on a world map, select Enter Station on Map. A world map will be displayed. For the 'Geostationary' case, 2 ground sites, will be displayed. To select the location of the uplink ground site, 'Click' the mouse at the desired location and the uplink site will move to that location. To select the location, select Second Ground Site and repeat the process. At the conclusion of this step the original display will appear with the selected latitudes and longitudes entered. The selection of the ground site for other orbital entries is the same except that the second ground sit is omitted.
Whether the ground station location is entered manually or on the world map, the user still needs to input the minimum antenna elevation, again in decimal degrees.
Stack Info
Stack Map
Link
Orbital
Ground
Ground Trace
Rise & Set


Time Information for Ground Trace
In order to observe the ground trace of the satellite this program requires some information in addition to the orbital elements and ground station information. The program needs to know what time to start the observation, how long to observe and the time step between each observation. Upon opening the card 'Select Observation Time And Time Steps' the program will input the satellite period, 'Observation Time' based upon one period, and the current date and time based upon the computer's internal clock. To modify 'Observation Time', enter the desired observation time in Hours and Minutes (HH:MM). Do not exceed 24 hours. To modify 'Time to Begin Observation', enter the appropriate time in Hours and Minutes (HH:MM). Be certain that all time entries have 5 characters, 2 digits, a colon and 2 digits!
Also available is a time zone selection. The time zone is based upon the Ground Station's geographic location. The Prime Meridian (+/-7.5° Longitude) is established as the center for Zulu Time (Zulu). The remaining time zones are split every 15° of Longitude. Local Standard Time (LST) is assumed to be the computer's internal time. Daylight Savings Time (DST) is LST - 1 Hour. Zulu is LST plus a time zone correction. The time zone correction is a positive integer, from 1 to 12, for Ground Station Longitudes in the Western hemisphere and a negative integer, from -1 to -12, for Ground Station Longitudes in the Eastern hemisphere.
Continue
Stack Info
Stack Map
Link
Orbital
Ground
Ground Trace
Rise & Set


Time Information for Ground Trace
To modify 'Date of Observation' enter the desired date: Month,Day,Year (MM/DD/YY)
The 'Time Step' determines the interval between each successive observation. Five different Time Steps are available; 1.5 Minute, 3.0 Minute, 6.0 Minute, 9.0 Minute and 15.0 Minute. The appropriate recommendations for time steps are as follows:
1.5 Minute: Recommended for orbit periods less than 90 minutes or close-up displays.
3.0 Minute: Recommended for orbit periods less than 2.5 Hours.
6.0 Minute: Recommended for orbit periods of 2 to 12 hours and small eccentricities.
9.0 Minute: Recommended for orbit periods of 6 hours or longer and highly eccentric orbits such as Molniya.
15.0 Minute: Recommended for geosynchronous orbits.
The Geosynchronous orbit is normally treated as a special case in this program, however if the user desires to model a geosynchronous orbit with various inclinations, the 15 minute time step is the appropriate selection.
To continue from the card 'Select Observation Time And Time Steps', select 'Continue'.
Continue
Return
Stack Info
Stack Map
Link
Orbital
Ground
Ground Trace
Rise & Set

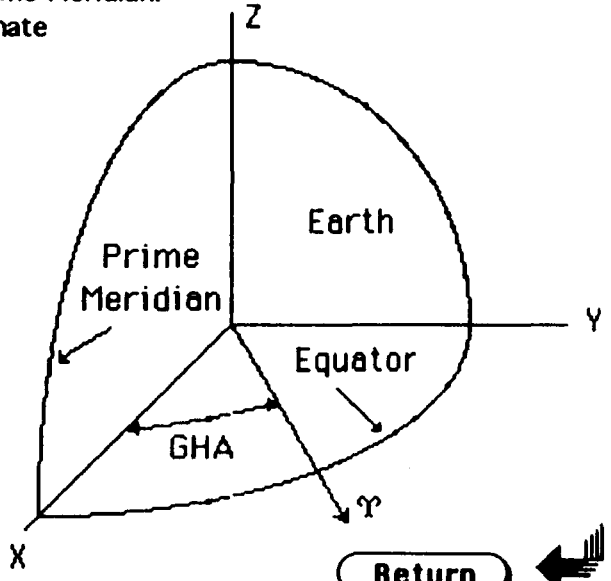

Map and Swath Options for Ground Trace
The 'Select the Map and Swath options' card offers 15 different maps upon which to observe the orbit ground trace. The default selection is the 'Global' map. It is recommended to plot the track the first time through on the 'Global' map. After that select any of the other 14 geographic locations covered by the ground trace. The Swath options consist of 'Ground Swath', 'Continuous' and 'Individual'. The ground swath is the satellite's field of view of the earth based upon the Ground Station's minimum antenna elevation. Currently the program does not allow the user to model the satellite's actual antenna pattern. To observe the ground swath first select 'Ground Swath'. 'Continuous' and 'Individual' will appear. To observe the total coverage of the satellite throughout the orbit select 'Continuous'. To observe the field of view at each observation interval select 'Individual'. Once all of the desired options are selected, select 'Plot Track' to watch the ground trace. The time it takes to plot the orbit will depend upon the speed of the machine the user is operating. Be patient, especially if any of the ground swath options are selected.
As the track is plotted, the time step and time elapsed (Zulu time) is displayed on the map. Upon completion of 'Plot Track', the user may step back through the orbit by selecting the appropriate arrow. If the user desires a hard copy of the displayed plot, select 'Print Card'. To
Continue
Return
Stack Info
Stack Map
Link
Orbital
Ground
Ground Trace
Rise & Set


Map and Swath Options for Ground Trace
return to the 'Select the Map and Swath options' card, select 'Ground Trace'. Back at the 'Select the Map and Swath options' card , if the user desires to review the completed plot or if the user wants to see what geographic areas are covered by the selected map, select 'Review'.
To save computer memory it is recommended that the user erase the plots when they are no longer needed. To erase, select 'Erase'. The user is greeted with three options; 'All', 'View' and 'Cancel'. By selecting 'Cancel' the user terminates the process. Selecting 'View' will erase all of the plots for the selected map and the selection of 'All' will erase all of the plots. At the completion of the 'Erase' function the stack will be compacted. If the user is operating this program from a disk drive the alert 'Failed to compact, Disk full.' will appear. This wil not effect the operation of this program, simply select 'OK'
If the user needs to change any of the observation time information, select 'Time Step'.
One item of information displayed on the 'Select the Map and Swath options' card is the Greenwich Hour Angle (GHA). In order to plot the ground trace of the orbit, which is referenced to earth centered inertial space in another coordinate system, that of the earth's, the program needs to know how the two coordinate systems relate to one another.
Continue
Return
Stack Info
Stack Map
Link
Orbital
Ground
Ground Trace
Rise & Set

Greenwich Hour Angle (GHA)

The coordinate system for the earth places the X Y plane through the equator with the X axis pointing from the center of the earth through the Prime Meridian. The Z axis is oriented toward true north. Both coordinate systems are centered at the same point and their respective Z axes are the same. For this program the essential difference between the two coordinate systems is the direction of the respective X axes. The angle between the two X axes is the GHA. The GHA is calculated using 'Time to Begin Observation' and the 'Date of Observation'. Using a known GHA of100.4602346° at 1200 Zulu, 1 January 2000 the GHA is derived from the following formula:

GHA= 100.4602346°
+ 0.985647348°/Day*Difference
+ 15.041068°/Hour*Zulu



Continue | Return

Stack Info | Stack Map | Link | Orbital | Ground | Ground Trace | Rise & Set

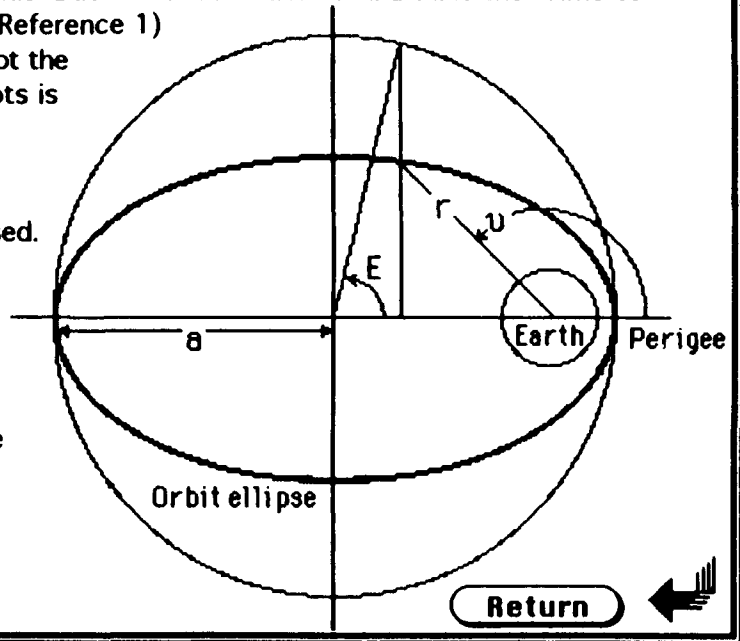
Kepler's Equation

where **Difference** is the known GHA date minus 'Date of Observation' and **Zulu** is the 'Time to Begin Observation' converted to Zulu time. (Reference 1)

Once the program knows the GHA it can plot the ground track. The beginning point for all plots is at the Ascending Node. A satellite's position in its orbit, as a functionof time, can only be solved directly for circular orbits. For elliptical orbits Kepler's Equation must be used. Kepler's Equation uses three quantities, the mean anomaly (M), the eccentric anomaly (E) and the mean motion (n). 'n' is defined by the following equation:

$$n=\sqrt{(\mu/a^3)}$$

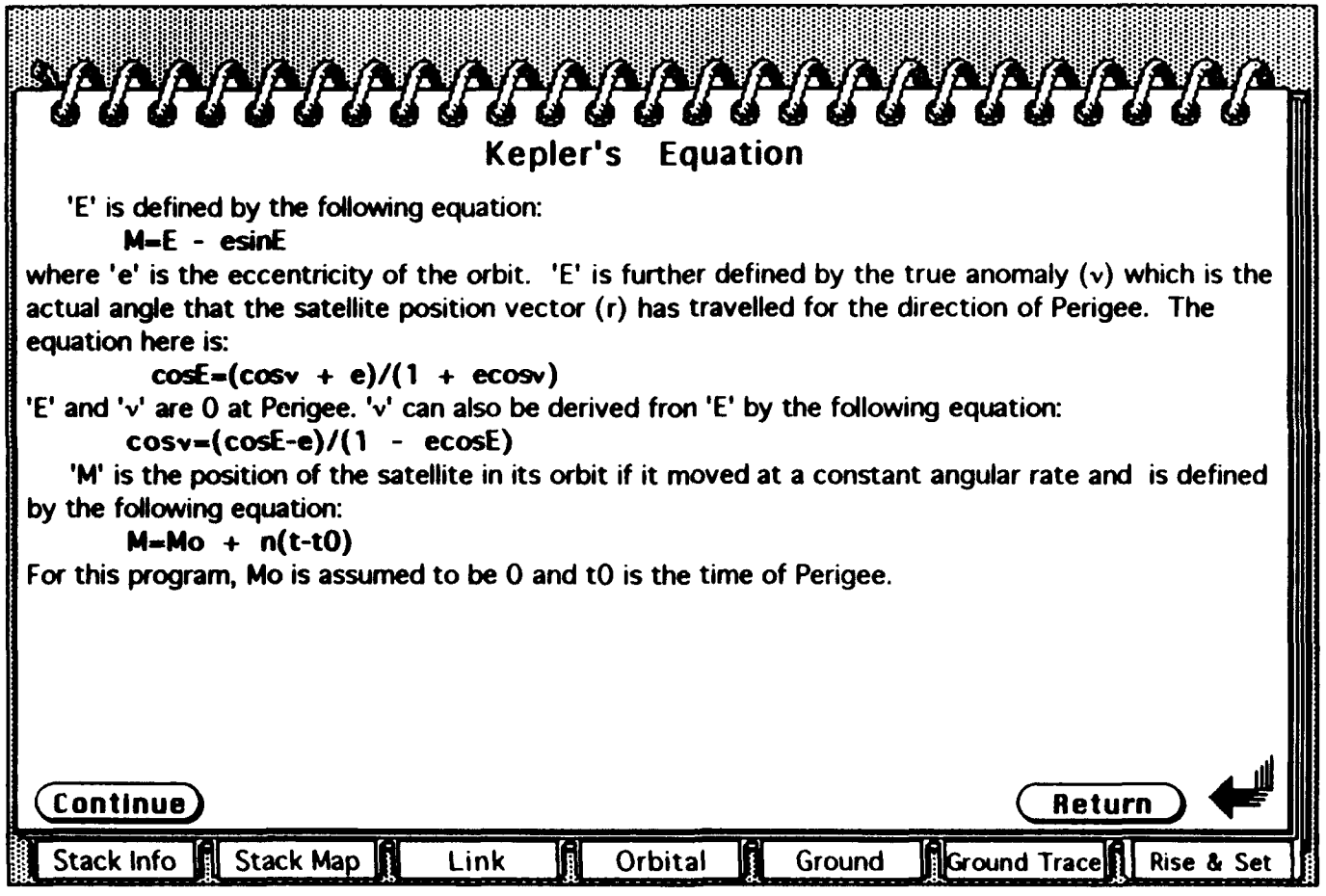
where 'a' is the Semimajor Axis and 'μ' is the gravitational parameter of the earth.

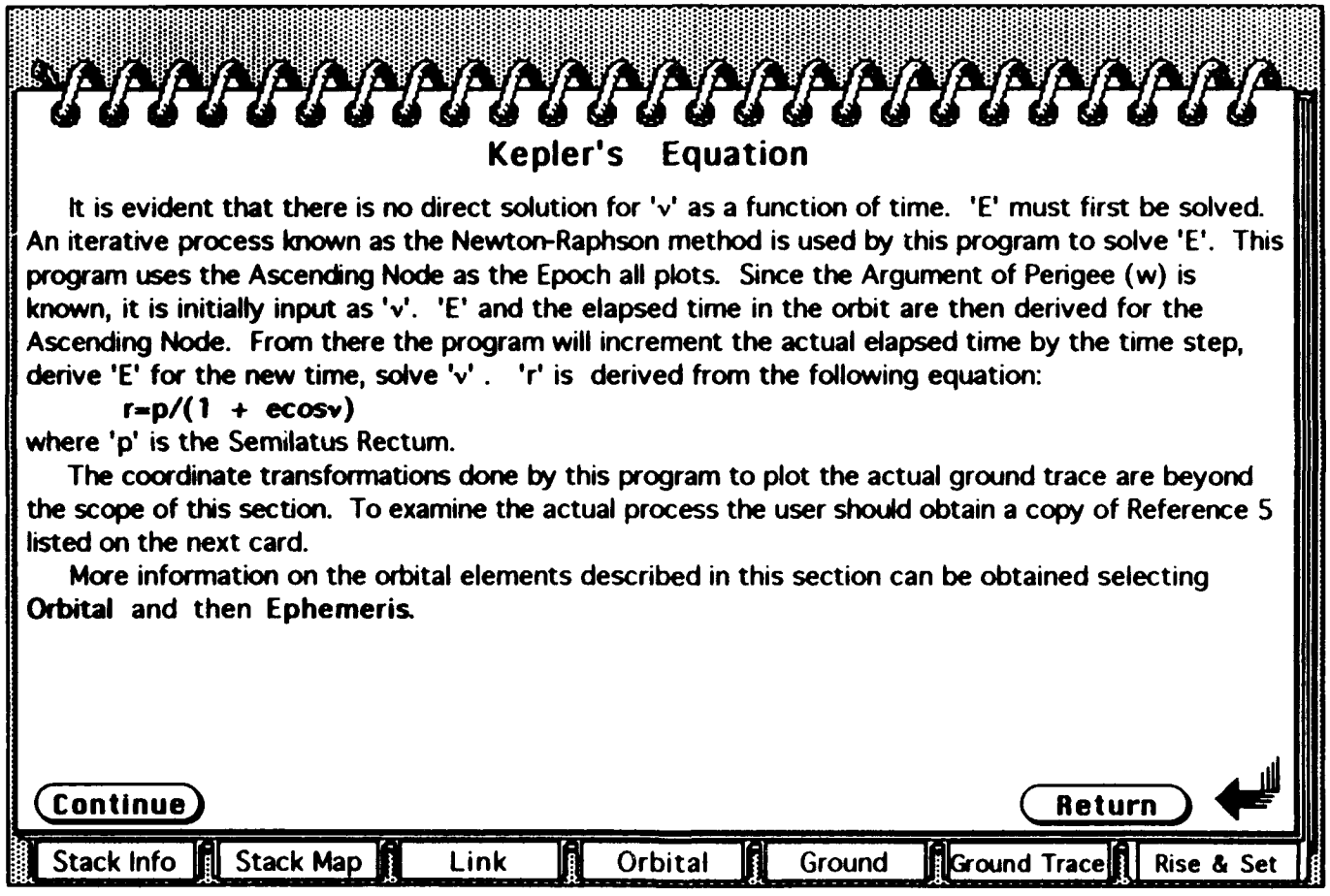


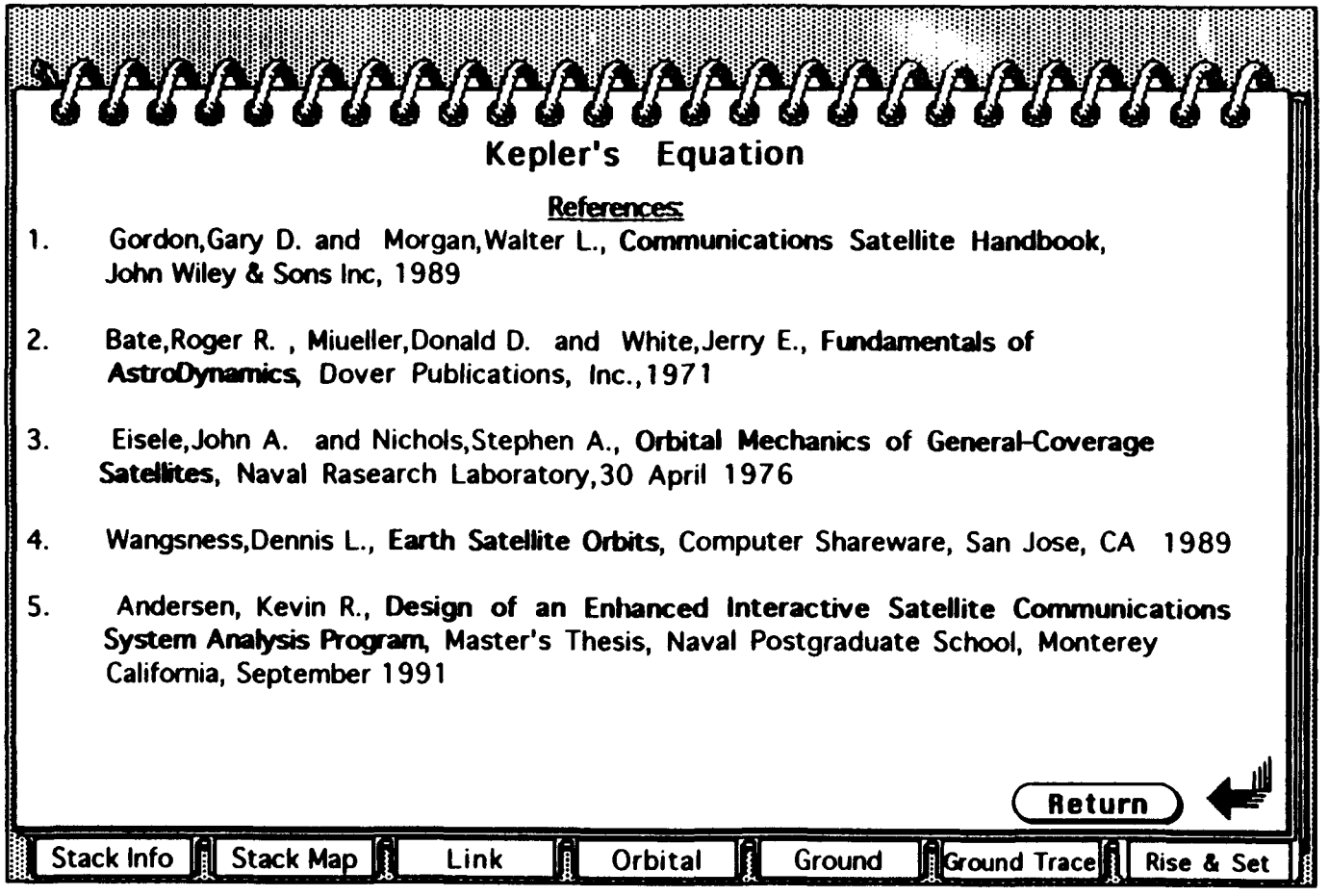
Continue

Return

Stack Info | Stack Map | Link | Orbital | Ground | Ground Trace | Rise & Set


Kepler's Equation
'E' is defined by the following equation:
M=E - esinE
where 'e' is the eccentricity of the orbit. 'E' is further defined by the true anomaly (ν) which is the actual angle that the satellite position vector (r) has travelled for the direction of Perigee. The equation here is:
cosE=(cosν + e)/(1 + ecosν)
'E' and 'ν' are 0 at Perigee. 'ν' can also be derived fron 'E' by the following equation:
cosν=(cosE-e)/(1 - ecosE)
'M' is the position of the satellite in its orbit if it moved at a constant angular rate and is defined by the following equation:
M=Mo + n(t-t0)
For this program, Mo is assumed to be 0 and t0 is the time of Perigee.
Continue
Return
Stack Info
Stack Map
Link
Orbital
Ground
Ground Trace
Rise & Set


Kepler's Equation
It is evident that there is no direct solution for 'v' as a function of time. 'E' must first be solved. An iterative process known as the Newton-Raphson method is used by this program to solve 'E'. This program uses the Ascending Node as the Epoch all plots. Since the Argument of Perigee (w) is known, it is initially input as 'v'. 'E' and the elapsed time in the orbit are then derived for the Ascending Node. From there the program will increment the actual elapsed time by the time step, derive 'E' for the new time, solve 'v' . 'r' is derived from the following equation:
r=p/(1 + ecosv)
where 'p' is the Semilatus Rectum.
The coordinate transformations done by this program to plot the actual ground trace are beyond the scope of this section. To examine the actual process the user should obtain a copy of Reference 5 listed on the next card.
More information on the orbital elements described in this section can be obtained selecting Orbital and then Ephemeris.
Continue
Return
Stack Info
Stack Map
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Orbital
Ground
Ground Trace
Rise & Set


Kepler's Equation
References:
1. Gordon,Gary D. and Morgan,Walter L., Communications Satellite Handbook, John Wiley & Sons Inc, 1989
2. Bate,Roger R. , Miueller,Donald D. and White,Jerry E., Fundamentals of AstroDynamics, Dover Publications, Inc.,1971
3. Eisele,John A. and Nichols,Stephen A., Orbital Mechanics of General-Coverage Satellites, Naval Rasearch Laboratory,30 April 1976
4. Wangsness,Dennis L., Earth Satellite Orbits, Computer Shareware, San Jose, CA 1989
5. Andersen, Kevin R., Design of an Enhanced Interactive Satellite Communications System Analysis Program, Master's Thesis, Naval Postgraduate School, Monterey California, September 1991
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Stack Info
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Rise & Set

Rise and Set Information

Upon selection of **'Rise and Set'** the 'Rise and Set' card is displayed. Access to this card is not available if the user has selected the **'Geostationary'** option. Displayed across the top of the card is the 'Beginning Time', 'Period' and 'Orbits per Day'. The 'Beginning Time' is the time to begin the observation as entered on the 'Select Observation Time and Time Steps' card. This time is automatically converted to Zulu time. 'Period' is the satellite's orbital period based upon the inputs from the **'Orbital Info'** section and 'Orbits per Day' is the number of orbits the satellite will complete in 24 hours.

This program allows the user to determine the satellite's rise time, rise compass azimuth, maximum antenna elevation, set time and set compass azimuth utilizing the ground stations minimum antenna elevation. The user may determine these parameters for any orbit beginning with the first orbit (starting at the 'Beginning Time') through the last complete orbit in a 24 hour period (based upon the lowest integer value of 'Orbits per Day'). The user may also choose to evaluate these parameters for any integer combination of orbits in between. The entry for the first orbit is on the left and the entry for the last orbit is on the right. The default settings are: 1 and 1.

When the user is satisfied with the entries, select **'Compute Rise and Set'**. The calculations may take time, depending upon the speed of user's machine, so be patient.

Continue



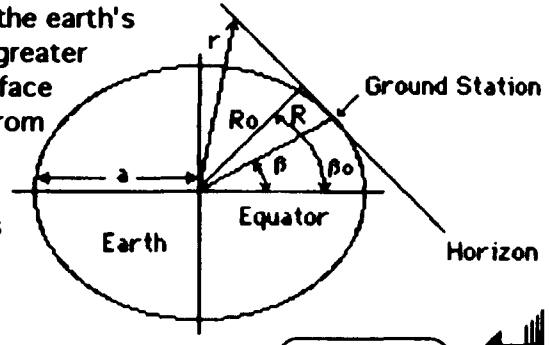
Stack Info | Stack Map | Link | Orbital | Ground | Ground Trace | Rise & Set

Rise and Set Information

The rise and set calculations must be accomplished if the user wishes to select the **'Latest Time In View'** option on the **'Ideal Link Budget'** card. In addition to the displayed parameters, **'Calculate Rise and Set'** finds the slant ranges for the rise, maximum antenna elevation and set times. To learn more about what is involved in the rise and set calculations, continue reading. Select the **'Return Arrow'** to return to the program.

'Calculate Rise and Set' is more accurate in determining whether or not the satellite comes into view of the ground station than the ground swaths displayed for **'Plot Track'**. The reason for this is **'Calculate Rise and Set'** factors in the oblateness of the earth into the calculation.

The exaggerated depiction of the earth illustrates that the earth's radius at the equator (a, average value, 6378.14 Km) is greater than its radius at the poles. Thus, a tangent line to the surface (equating to the horizon) is only perpendicular to a line from the center of the earth to the surface (R) at the poles and the equator. The satellite is considered in view (antenna elevation = 0°) when it appears above the ground station's horizon. In order to calculate the time, the progam transposes the satellite's position vector (r) on to the



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vector perpendicular to the horizon (Ro). When the magnitude of the transposition is greater than the magnitude of 'Ro', the satellite is above the horizon. The time of this occurance is the rise time. The process is duplicated for the set time only the criteria is changed to less than. 'R' is a function of 'a', the ground station's geographic latitude (β) and the earth's eccentricity (e, $\approx$ 0.081992) and is calculated with the following formula:

$$R = a\sqrt{[(1 - e^2)/(1 - (e \sin\beta)^2)]}$$

In order to find 'Ro' the program must first determine the geocentric latitude (β_o). 'β_o' is a function of 'e' and 'β'. The formula for 'β_o' is:

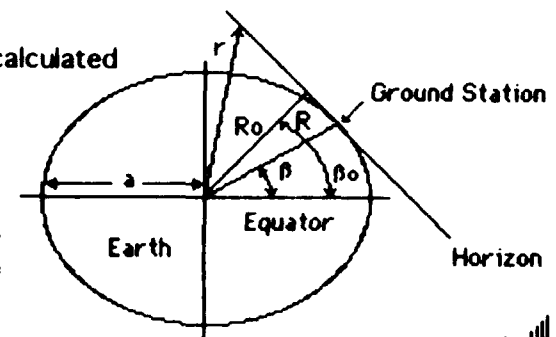
$$\beta_o = \arctan(\tan\beta/(1-e^2))$$

From there, 'Ro', which is a function of 'a', 'e' and 'β_o' is calculated with the following formula:

$$Ro = a\sqrt{[1 - (e \sin\beta_o)^2]}$$

The difference between 'R' and 'Ro' is minimal but the difference between 'R' and 'a' can range up to 21 Km.

When the satellite is at rise or set the position vectors of the ground station and satellite provide the information for antenna azimuth and elevation.



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The formula for calculating the azimuth angle (A) is as follows:

$$A = \arctan[\sin\Delta\lambda / (\cos\phi \tan\partial - \sin\phi \cos\Delta\lambda)]$$

where '$\Delta\lambda$' is the difference in the satellite's and ground station's longitude (°), 'ϕ' is the earth station's latitude (°) and '∂' is the sub-satellite point's latitude.

The formula for the true antenna elevation (h) is as follows:

$$h = \arctan[(\sinh\infty - R/r)/\cosh\infty]$$

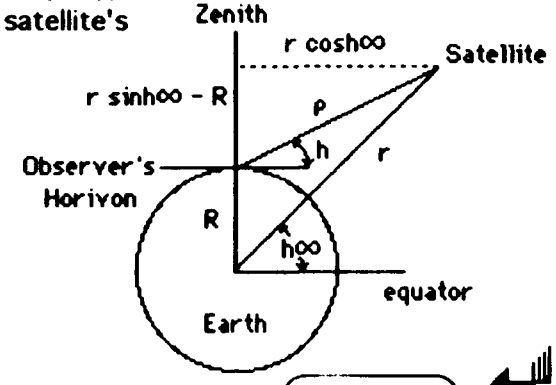
where 'R' is the radius of the earth corrected for oblateness (Km), 'r' is the radius of the satellite (42164 Km for a geostationary satellite) and '$h\infty$' is the satellite's elevation above the equator. '$h\infty$' is calculated with the following formula:

$$h\infty = \arcsin[\sin\partial \sin\phi + \cos\partial \cos\phi \cos\Delta\lambda]$$

The basic formula for calculating the slant range (d) is:

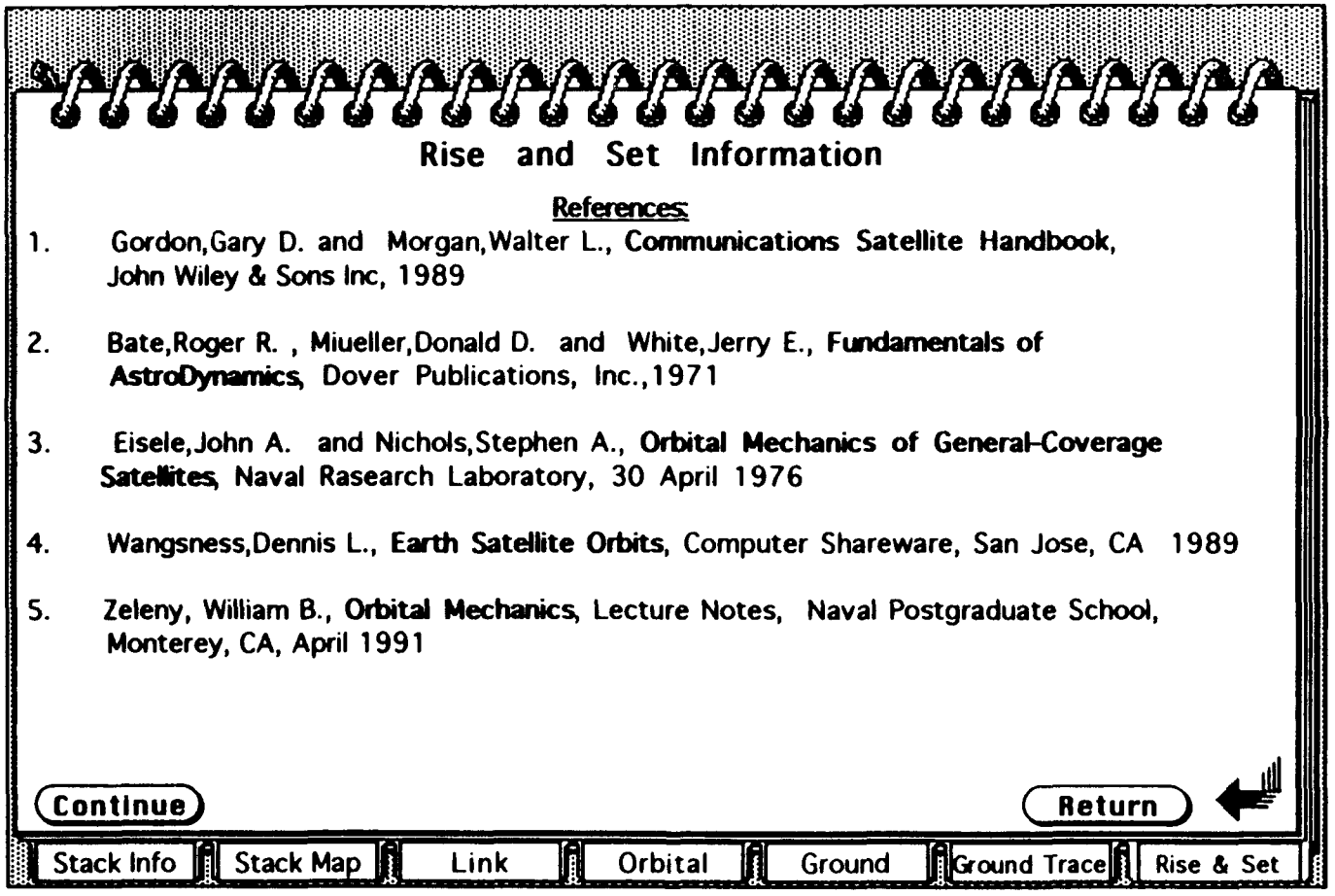
$$d = [\sqrt{(r^2 - Re^2 (\cos E)^2)}] - Re \sin E$$

where 'r' is the radius of the satellite (Km), 'Re' is the radius of the earth (6378 Km), and 'E' is the antenna elevation (°).



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Rise and Set Information
References:
1. Gordon,Gary D. and Morgan,Walter L., Communications Satellite Handbook, John Wiley & Sons Inc, 1989
2. Bate,Roger R. , Miueller,Donald D. and White,Jerry E., Fundamentals of AstroDynamics, Dover Publications, Inc.,1971
3. Eisele,John A. and Nichols,Stephen A., Orbital Mechanics of General-Coverage Satellites, Naval Rasearch Laboratory, 30 April 1976
4. Wangsness,Dennis L., Earth Satellite Orbits, Computer Shareware, San Jose, CA 1989
5. Zeleny, William B., Orbital Mechanics, Lecture Notes, Naval Postgraduate School, Monterey, CA, April 1991
Continue
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APPENDIX B: STACK SCRIPT

```
--------------
Script of Stack: "ENHANCED SATELLITE COMMUNICATIONS ANALYSIS PROGRAM (ESCAP)"
--------------
-- TITLE:          Enhanced Satellite Communications Analysis Program
-- AUTHOR:         Kevin R. Andersen
-- DATE:           21 MARCH 1991
-- REVISED:        8 September 1991
-- DESCRIPTION:    This program is written in partial fulfillment of the
--                 requirements for the degree of Master of Science
--                 (Systems Technology) from the Naval Postgraduate School,
--                 Monterey, CA. The program has not been verified!
-- -- -- -- -- -- --
on openStack
  global orbitPage,groundPage,commPage,begin,mu,Re,c,dBk,r2d,d2r,we
  global earth_e,Noise,TIV,Losses
  put false into orbitPage
  put false into groundPage
  put false into commPage
  put false into Noise
  put false into TIV
  put false into Losses
  put true into begin
  put 398601.2 into mu
  put 6378 into Re
  put 2.997925*10^8 into c
  put -228.599 into dBk
  put 180/pi into r2d
  put pi/180 into d2r
  put .00007292115856 into we
  put 0.081992 into earth_e
  set cmdChar of menuItem 2 of menu "Options" to D
end openStack
-- -- -- -- -- -- --
function FreqToWave freq
  global c
  put c/(freq*10^9) into wave
  return wave
end FreqToWave
-- -- -- -- -- -- --
function log s
  put ln(s)/ln(10) into it
  return it
end log
-- -- -- -- -- -- --
function num s
```

```
  put exp(s/4.342944) into it
  return it
end num
-- -- -- -- -- --
function aSin sinAng
  put sqrt(1 - sinAng*sinAng) into cosAng
  if cosAng <> 0 then
    put Atan(sinAng cosAng) into ang
  else
    put sinAng*pi abs(2*sinAng) into ang
  end if
  return ang
end aSin
-- -- -- -- -- --
function aCos cosAng
  if cosAng <> 0 then
    put sqrt(1-cosAng*cosAng) into sinAng
    put sinAng/cosAng into tanAng
    put atan(tanAng) into ang
    if ang < pi then
      put ang + pi into ang
    end if
  else
    put pi/2 into ang
  end if
  return ang
end aCos
-- -- -- -- -- --
function aTan2 x,y
  put sqrt(x*x + y*y) + x into denom
  if denom > 0 then
    put 2*aTan(y/denom) into ang
  else
    put pi into ang
  end if
  return ang
end aTan2
-- -- -- -- -- --
function GeodedicLat Glat
  put 0.081992 into e
  put atan(tan(Glat)/(1-e^2)) into GeoLat
  return GeoLat
end GeodedicLat
-- -- -- -- -- --
function GeodedicR GeoLat
  put 0.081992 into e
  put 6378.4 into a
  put a*sqrt(1-e^2*sin(GeoLat)^2) into R
  return R
end GeodedicR
-- -- -- -- -- --
```

```
function SlantRange r,Re,true_el
 put r^2 - Re^2*(cos(true_el))^2 into pt1
 put Re*sin(true_el) into pt2
 put sqrt(pt1) - pt2 into SR
 return SR
end SlantRange
-- -- -- -- -- --
function Azimuth del_lon,Glat,satLat
 put cos(Glat)*tan(satLat) - sin(Glat)*cos(del_lon) into denom
 put sin(del_lon) into num
 if satLat = Glat then
  if del_lon < 0 then
   put pi/2 into ang
   put ang*180/pi into angDeg
  else if del_lon > 0 then
   put 3*pi/2 into ang
   put ang*180/pi into angDeg
  end if
 else if denom = 0 then
  put "Zenith" into angDeg
 else
  put atan(-num/denom) into ang_rough
  if num < 0 and denom < 0 then
   put pi + ang_rough into ang
  else if num > 0 and denom < 0 then
   put pi + ang_rough into ang
  else if num > 0 and denom > 0 then
   put 2*pi + ang_rough into ang
  else if num = 0 and denom <0 then
   put pi into ang
  else
   put ang_rough into ang
  end if
  put ang*180/pi into angDeg
 end if
 return angDeg
end Azimuth
-- -- -- -- -- --
function TimeChange time
 put the length of time into x
 if last char of time is "M" then
  if char (x - 1) of time is "P" then
   if char 2 of time is ":" then
    put char 1 of time + 12 into HH
    put char 3 to 4 of time into MM
   else if char 2 of time is "2" then
    put char 1 to 2 of time into HH
    put char 4 to 5 of time into MM
   else
    put char 1 to 2 of time + 12 into HH
    put char 4 to 5 of time into MM
```

```
      end if
    else if char 2 of time is ":" then
      put "0" & char 1 of time into HH
      put char 3 to 4 of time into MM
    else if char 2 of time is "2" then
      put "00" into HH
      put char 4 to 5 of time into MM
    else
      put char 1 to 2 of time into HH
      put char 4 to 5 of time into MM
    end if
  else if x = 4 then
    put "0" & char 1 of time into HH
    put char 3 to 4 of time into MM
  else
    put char 1 to 2 of time into HH
    put char 4 to 5 of time into MM
  end if
  put HH & ":" & MM into Time24
  return Time24
end TimeChange
-- -- -- -- -- --
on Newton_Raphson
  global E,t,meanMotion,ecc
  -- Newton Raphson solution to the Eccentric Anomaly
  put 1 into dE
  repeat while abs(dE) > .01
    put t - meanMotion*(E - ecc*sin(E)) into f
    put -meanMotion*(1 - ecc*cos(E)) into df
    put -f df into dE
    put E + dE into E
  end repeat
end Newton_Raphson
-- -- -- -- -- --
on MaxLonCheck
  global lon,Glon,lonV,maxLon,lonCk,GlonCk
  global lonVck,maxLonCk,PlotType,Map
  if PlotType is "Sub Satellite" then
    put lon into l
  else if PlotType is "Ground Site" then
    put Glon into l
  else if PlotType is "Field of View" then
    put lonV into l
  end if
  if Map is "North Pacific" then
    if l < 0 then
      put 2*pi + l into lCk
    else put l into lCk
    put 2*pi + maxLon into maxLonCk
  else if Map is "South Pacific" then
    if l < 0 then
```

```
      put 2*pi + l into lCk
    else put l into lCk
    put 2*pi + maxLon into maxLonCk
  else
    put l into lCk
    put maxLon into maxLonCk
  end if
  if PlotType is "Sub Satellite" then
    put lCk into lonCk
  else if PlotType is "Ground Site" then
    put lCk into GlonCk
  else if PlotType is "Field of View" then
    put lCk into lonVck
  end if
end MaxLonCheck
-- -- -- -- -- --
on Swath_Width
  global lat,lon,z,r,Re,ant_el,t1,t2,dphi,e1,e2,e3
  global n1,n2,n3,p1,p2,p3,earth_e,cEl,sEl
  put 0.081992 into earth_e
  put sin(lat) into sLat
  put cos(lat) into cLat
  put sin(lon) into sLon
  put cos(lon) into cLon
  put sin(ant_el) into sEl
  put cos(ant_el) into cEl
  put cLat*cLon into p1
  put cLat*sLon into p2
  put sLat into p3
  -- Get Sub Satellite R
  -- put atan(tan(lat)/(1-earth_e^2)) into GeoLat
  -- put Re*sqrt(1 - earth_e^2*sin(GeoLat)^2) into R_Oblong
  if abs(z) is not 1 then
    put sqrt(p1^2 + p2^2) into length
    -- Find the east unit vector
    put -p2/length into e1
    put p1/length into e2
    put 0 into e3
    -- Find the north unit vector
    put -p3*e2 into n1
    put p3*e1 into n2
    put p1*e2 - p2*e1 into n3
  else
    put 1 into e1
    put 0 into e2
    put 0 into e3
    put 0 into n1
    put 1 into n2
    put 0 into n3
  end if
  put SlantRange(r,Re,ant_el) into range
```

```
  put Re + range*sEl into t1
  put range*cEl into t2
  put pi/15 into dphi
end Swath_Width
-- -- -- -- -- --
on Interpolate
  global PlotType,xS,yS,oldXs,oldYs,yV,xV,oldYv,oldXv
  if PlotType is "Sub Satellite" then
    put xS into xN
    put yS into yN
    put oldXs into xO
    put oldYs into yO
  else if PlotType is "Field of View" then
    put xV into xN
    put yV into yN
    put oldXv into xO
    put oldYv into yO
  end if
  if xN - xO < 0 then
    put 507 + xN into x1
    put (yN-yO)/(x1-xO) into m
    put yO + m*(509 - xO) into y
   drag from round(xO),round(yO) to 509,round(y)
   drag from 2,round(y) to round(xN),round(yN)
  end if
  if xN - xO > 0 then
    put -507 + xN into x1
    put (yN-yO)/(x1-xO) into m
    put yO + m*(2 - xO) into y
   drag from round(xO),round(yO) to 2,round(y)
   drag from 509,round(y) to round(xN),round(yN)
  end if
end Interpolate
-- -- -- -- -- --
on OrbitXform
  global asnDeg,perDeg,incDeg,GHAdeg,ex,ey,ez,vx,vy,vz,E,sinE,cosE
  global d2r,r2d,t0,meanMotion,ecc,param,a
  -- Convert angles in deg to angles in radians
  if perDeg < -180 then put perDeg+360 into perDeg
  if perDeg > 180 then put perDeg - 360 into perDeg
  put pi/180 into d2r
  put asnDeg*d2r into asn
  put perDeg*d2r into per
  put incDeg*d2r into inc
  put GHAdeg*d2r into GHA
  -- Get components of unit vectors
  -- Unit vector pointing toward ascending node (n)
  put cos(asn + GHA) into nx
  put sin(asn + GHA) into ny
  put 0 into nz
  -- Unit vector normal to the plane (h)
```

```
  put sin(inc)*sin(asn + GHA) into hx
  put -sin(inc)*cos(asn + GHA) into hy
  put cos(inc) into hz
  -- Get vector in plane perpendicular to n, given by nxh
  put hy*nz - hz*ny into ux
  put hz*nx - hx*nz into uy
  put hx*ny - hy*nx into uz
  -- Get unit vector pointing toward perigee (e)
  put cos(per) into cosPer
  put sin(per) into sinPer
  put cosPer*nx + sinPer*ux into ex
  put cosPer*ny + sinPer*uy into ey
  put cosPer*nz + sinPer*uz into ez
  -- Get vector perpendicular to e and in plane of orbit. v is
  -- in the direction of the Semi-Latus Rectum (param)
  put hy*ez - hz*ey into vx
  put hz*ex - hx*ez into vy
  put hx*ey - hy*ex into vz
  put (ecc + cos(-per))/(1 + ecc*cos(-per)) into cosE
  put param/(1+ecc*cos(-per)) into r0
  put r0*sin(-per)/(a*sqrt(1-ecc*ecc)) into sinE
  put aTan2(cosE,sinE) into E
  put meanMotion*(E - ecc*sin(E)) into t0
end OrbitXform
-- -- -- -- -- --
on PlotMap
  global lon,lat,Glon,Glat,lonV,latV,aLon,aLat,bLon,bLat,cLon,cLat
  global xS,yS,gxS,gyS,xV,yV,Map,PlotType
  if PlotType is "Sub Satellite" then
    put lon into longitude
    put lat into latitude
  else if PlotType is "Ground Site" then
    put Glon into longitude
    put Glat into latitude
  else if PlotType is "Field of View" then
    put lonV into longitude
    put latV into latitude
  end if
  if Map is "Global Map" then
    put aLon + bLon*longitude into x
    put aLat + bLat*latitude into y
  else if Map is "North Pole" then
    put 255 + sin(-longitude)*(pi/2 - latitude)*296.028 into x
    put 172 - cos(-longitude)*(pi/2 - latitude)*296.028 into y
  else if Map is "South Pole" then
    put 255 + sin(longitude)*sin(pi/2 + latitude)*247.327 into x
    put 124 - cos(longitude)*sin(pi/2 + latitude)*247.327 into y
  else if Map is "North Pacific" then
    if longitude < 0 then
      add 2*pi to longitude
    end if
```

```
    put aLon + bLon*(longitude - cLon) into x
    put aLat + bLat*(latitude - cLat) into y
   else if Map is "South Pacific" then
    if longitude < 0 then
     add 2*pi to longitude
    end if
    put aLon + bLon*(longitude - cLon) into x
    put aLat + bLat*(latitude - cLat) into y
   else
    put aLon + bLon*(longitude - cLon) into x
    put aLat + bLat*(latitude - cLat) into y
   end if
   if PlotType is "Sub Satellite" then
    put x into xS
    put y into yS
   else if PlotType is "Ground Site" then
    put x into gxS
    put y into gyS
   else if PlotType is "Field of View" then
    put x into xV
    put y into yV
   end if
end PlotMap
-- -- -- -- -- --
function Lat V
  put 160 - V into t
  if V <= 160 then
    put t*(0.76923 - .226595*(t/160)) into Glat
  else if V > 160 then
    put t*(0.76923 + .226595*(t/160)) into Glat
  end if
  return Glat
end Lat
-- -- -- -- -- --
function PositLat Glat
  put Glat*(180/pi) into GlatDeg
  if GlatDeg >= 0 then
    put 0.226595/160 into a
    put -0.76923 into b
    put GlatDeg into c
   put (-b - sqrt(b^2-4*a*c))/(2*a) into t
  else if GlatDeg < 0 then
    put 0.226595/160 into a
    put 0.76923 into b
    put -GlatDeg into c
   put (-b + sqrt(b^2-4*a*c))/(2*a) into t
  end if
  put 160 - t into V
  return round(V)
end PositLat
-- -- -- -- -- --
```

```
function PositLon Glon
  put Glon*467/(2*pi) + 254.5 into H
  return round(H)
  -- put (H - 254.5)*(2*pi)/467 into Glon
end PositLon
-- -- -- -- -- --
---------------
```

APPENDIX C: BACKGROUND SCRIPTS

```
--------------
Script of Background "General"
--------------
-- -- -- -- -- -- --
function FindRegion region
 if first char of region is "D" then
  if char 2 of region > "3" then
   put "D2" into rainRegion
  else put char 1 to 2 of region into rainRegion
 else
  put char 1 of region into rainRegion
 end if
 return rainRegion
end FindRegion
-- -- -- -- -- -- --
on FillRegion
 global rainRegion
 lock screen
 -- this section loads the surface point rain rate numbers into the 12 flds
 -- corresponding to the 12 %s of rainfall per year based on the selected
 -- rain climate region
 if rainRegion="A" then
  put "A" into cd fld "Region"
  put 28.5 into cd fld 4
  put 21 into cd fld 5
  put 13.5 into cd fld 6
  put 10.0 into cd fld 7
  put 7 into cd fld 8
  put 4 into cd fld 9
  put 2.5 into cd fld 10
  put 1.5 into cd fld 11
  put 0.7 into cd fld 12
  put 0.4 into cd fld 13
  put 0.1 into cd fld 14
  put 0.0 into cd fld 15
 else if rainRegion="B" then
  put "B" into cd fld "Region"
  put 57.5 into cd fld 4
  put 44 into cd fld 5
  put 28.5 into cd fld 6
  put 19.5 into cd fld 7
  put 13.5 into cd fld 8
  put 8 into cd fld 9
  put 5.2 into cd fld 10
  put 3.4 into cd fld 11
```

```
  put 1.9 into cd fld 12
  put 1.7 into cd fld 13
  put 1.3 into cd fld 14
  put 0.3 into cd fld 15
else if rainRegion="C" then
  put "C" into cd fld "Region"
  put 78 into cd fld 4
  put 62 into cd fld 5
  put 41 into cd fld 6
  put 28 into cd fld 7
  put 18 into cd fld 8
  put 11 into cd fld 9
  put 7.2 into cd fld 10
  put 4.8 into cd fld 11
  put 2.7 into cd fld 12
  put 1.8 into cd fld 13
  put 1.1 into cd fld 14
  put 0.5 into cd fld 15
else if rainRegion="D1" then
  put "D1" into cd fld "Region"
  put 90 into cd fld 4
  put 72 into cd fld 5
  put 50 into cd fld 6
  put 35.5 into cd fld 7
  put 24 into cd fld 8
  put 14.5 into cd fld 9
  put 9.8 into cd fld 10
  put 6.4 into cd fld 11
  put 3.6 into cd fld 12
  put 2.2 into cd fld 13
  put 1.2 into cd fld 14
  put 0.0 into cd fld 15
else if rainRegion="D2" then
  put "D2" into cd fld "Region"
  put 108 into cd fld 4
  put 89 into cd fld 5
  put 64.5 into cd fld 6
  put 49 into cd fld 7
  put 35 into cd fld 8
  put 22 into cd fld 9
  put 14.5 into cd fld 10
  put 9.5 into cd fld 11
  put 5.2 into cd fld 12
  put 3 into cd fld 13
  put 1.5 into cd fld 14
  put 0.0 into cd fld 15
else if rainRegion="D3" then
  put "D3" into cd fld "Region"
  put 126 into cd fld 4
  put 106 into cd fld 5
  put 80.5 into cd fld 6
```

```
    put 63 into cd fld 7
    put 48 into cd fld 8
    put 32 into cd fld 9
    put 22 into cd fld 10
    put 14.5 into cd fld 11
    put 7.8 into cd fld 12
    put 4.7 into cd fld 13
    put 1.9 into cd fld 14
    put 0.0 into cd fld 15
  else if rainRegion="E" then
    put "E" into cd fld "Region"
    put 165 into cd fld 4
    put 144 into cd fld 5
    put 118 into cd fld 6
    put 98 into cd fld 7
    put 78 into cd fld 8
    put 52 into cd fld 9
    put 35 into cd fld 10
    put 21 into cd fld 11
    put 10.6 into cd fld 12
    put 6 into cd fld 13
    put 2.9 into cd fld 14
    put 0.0 into cd fld 15
  else if rainRegion="F" then
    put "F" into cd fld "Region"
    put 66 into cd fld 4
    put 51 into cd fld 5
    put 34 into cd fld 6
    put 23 into cd fld 7
    put 15 into cd fld 8
    put 8.3 into cd fld 9
    put 5.2 into cd fld 10
    put 3.1 into cd fld 11
    put 1.4 into cd fld 12
    put 0.7 into cd fld 13
    put 0.2 into cd fld 14
    put 0.0 into cd fld 15
  else if rainRegion="G" then
    put "G" into cd fld "Region"
    put 185 into cd fld 4
    put 157 into cd fld 5
    put 120.5 into cd fld 6
    put 94 into cd fld 7
    put 72 into cd fld 8
    put 47 into cd fld 9
    put 32 into cd fld 10
    put 21.8 into cd fld 11
    put 12.2 into cd fld 12
    put 8 into cd fld 13
    put 5 into cd fld 14
    put 1.8 into cd fld 15
```

```
  else
    put "H" into cd fld "Region"
    put 253 into cd fld 4
    put 220.5 into cd fld 5
    put 178 into cd fld 6
    put 147 into cd fld 7
    put 119 into cd fld 8
    put 86.5 into cd fld 9
    put 64 into cd fld 10
    put 43.5 into cd fld 11
    put 22.5 into cd fld 12
    put 12 into cd fld 13
    put 5.2 into cd fld 14
    put 1.2 into cd fld 15
  end if
end FillRegion
-- -- -- -- -- --
function calculate0Cisotherm Glat,Case
  put abs(Glat) into Latitude
  -- if hilite of cd btn 7 = true or hilite of cd btn 8 = true or ¬
  -- hilite of cd btn 9 = true then put "1" into Case
  -- else if hilite of cd btn 10 = true or hilite of cd btn 11 = true or ¬
  -- hilite of cd btn 12 = true then put "2" into Case
  -- else if hilite of cd btn 13 = true or hilite of cd btn 14 = true or ¬
  -- hilite of cd btn 15 = true then put "3" into Case
  -- else if hilite of cd btn 16 = true or hilite of cd btn 17 = true or ¬
  -- hilite of cd btn 18 = true then put "4" into Case
  if latitude>=0 and latitude<=20 then
    if Case="1" then put 5.4 into H
    if Case="2" then put 5.2 into H
    if Case="3" then put 4.85 into H
    if Case="4" then put 4.5 into H
  end if
  if latitude>=21 and latitude<=30 then
    if Case="1" then put 5.3 into H
    if Case="2" then put 5 into H
    if Case="3" then put 4.5 into H
    if Case="4" then put 4 into H
  end if
  if latitude>=31 and latitude<=35 then
    if Case="1" then put 5 into H
    if Case="2" then put 4.5 into H
    if Case="3" then put 3.9 into H
    if Case="4" then put 3.2 into H
  end if
  if latitude>=36 and latitude<=40 then
    if Case="1" then put 4.7 into H
    if Case="2" then put 4 into H
    if Case="3" then put 3.3 into H
    if Case="4" then put 2.4 into H
  end if
```

```
if latitude>=41 and latitude<=45 then
  if Case="1" then put 4.4 into H
  if Case="2" then put 3.6 into H
  if Case="3" then put 2.7 into H
  if Case="4" then put 1.8 into H
end if
if latitude>=46 and latitude<=50 then
  if Case="1" then put 4 into H
  if Case="2" then put 3.2 into H
  if Case="3" then put 2.2 into H
  if Case="4" then put 1.2 into H
end if
if latitude>=51 and latitude<=55 then
  if Case="1" then put 3.6 into H
  if Case="2" then put 2.7 into H
  if Case="3" then put 1.7 into H
  if Case="4" then put .7 into H
end if
if latitude>=56 and latitude<=60 then
  if Case="1" then put 3.1 into H
  if Case="2" then put 2.2 into H
  if Case="3" then put 1.3 into H
  if Case="4" then put .4 into H
end if
if latitude>=61 and latitude<=65 then
  if Case="1" then put 2.7 into H
  if Case="2" then put 1.8 into H
  if Case="3" then put 1 into H
  if Case="4" then put .2 into H
end if
if latitude>=66 then
  if Case="1" then put 2.3 into H
  if Case="2" then put 1.6 into H
  if Case="3" then put .8 into H
  if Case="4" then put .01 into H
end if
return H
end calculate0Cisotherm
-- -- -- -- -- --
function FindRate rainRegion,Percent
 -- this section loads the surface point rain rate numbers into the 12 flds
 -- corresponding to the 12 %s of rainfall per year based on the selected
 -- rain climate region
 if rainRegion="A" then
   if Percent <= 0.002 then put 28.5 into Rate
   else if Percent <= 0.005 then put 21 into Rate
   else if Percent <= 0.01 then put 13.5 into Rate
   else if Percent <= 0.02 then put 10.0 into Rate
   else if Percent <= 0.05 then put 7 into Rate
   else if Percent <= 0.1 then put 4 into Rate
   else if Percent <= 0.2 then put 2.5 into Rate
```

```
  else if Percent <= 0.5 then put 1.5 into Rate
  else if Percent <= 1.0 then put 0.7 into Rate
  else if Percent <= 2.0 then put 0.4 into Rate
  else put 0.1 into Rate
else if rainRegion="B" then
  if Percent <= 0.002 then put 57.5 into Rate
  else if Percent <= 0.005 then put 44 into Rate
  else if Percent <= 0.01 then put 28.5 into Rate
  else if Percent <= 0.02 then put 19.5 into Rate
  else if Percent <= 0.05 then put 13.5 into Rate
  else if Percent <= 0.1 then put 8 into Rate
  else if Percent <= 0.2 then put 5.2 into Rate
  else if Percent <= 0.5 then put 3.4 into Rate
  else if Percent <= 1.0 then put 1.9 into Rate
  else if Percent <= 2.0 then put 1.7 into Rate
  else put 1.3 into Rate
else if rainRegion="C" then
  if Percent <= 0.002 then put 78 into Rate
  else if Percent <= 0.005 then put 62 into Rate
  else if Percent <= 0.01 then put 41 into Rate
  else if Percent <= 0.02 then put 28 into Rate
  else if Percent <= 0.05 then put 18 into Rate
  else if Percent <= 0.1 then put 11 into Rate
  else if Percent <= 0.2 then put 7.2 into Rate
  else if Percent <= 0.5 then put 4.8 into Rate
  else if Percent <= 1.0 then put 2.7 into Rate
  else if Percent <= 2.0 then put 1.8 into Rate
  else put 1.1 into Rate
else if rainRegion="D1" then
  if Percent <= 0.002 then put 90 into Rate
  else if Percent <= 0.005 then put 72 into Rate
  else if Percent <= 0.01 then put 50 into Rate
  else if Percent <= 0.02 then put 35.5 into Rate
  else if Percent <= 0.05 then put 24 into Rate
  else if Percent <= 0.1 then put 14.5 into Rate
  else if Percent <= 0.2 then put 9.8 into Rate
  else if Percent <= 0.5 then put 6.4 into Rate
  else if Percent <= 1.0 then put 3.6 into Rate
  else if Percent <= 2.0 then put 2.2 into Rate
  else put 1.2 into Rate
else if rainRegion="D2" then
  if Percent <= 0.002 then put 108 into Rate
  else if Percent <= 0.005 then put 89 into Rate
  else if Percent <= 0.01 then put 64.5 into Rate
  else if Percent <= 0.02 then put 49 into Rate
  else if Percent <= 0.05 then put 35 into Rate
  else if Percent <= 0.1 then put 22 into Rate
  else if Percent <= 0.2 then put 14.5 into Rate
  else if Percent <= 0.5 then put 9.5 into Rate
  else if Percent <= 1.0 then put 5.2 into Rate
  else if Percent <= 2.0 then put 3 into Rate
```

```
  else put 1.5 into Rate
 else if rainRegion="D3" then
  if Percent <= 0.002 then put 126 into Rate
  else if Percent <= 0.005 then put 106 into Rate
  else if Percent <= 0.01 then put 80.5 into Rate
  else if Percent <= 0.02 then put 63 into Rate
  else if Percent <= 0.05 then put 48 into Rate
  else if Percent <= 0.1 then put 32 into Rate
  else if Percent <= 0.2 then put 22 into Rate
  else if Percent <= 0.5 then put 14.5 into Rate
  else if Percent <= 1.0 then put 7.8 into Rate
  else if Percent <= 2.0 then put 4.7 into Rate
  else put 1.9 into Rate
 else if rainRegion="E" then
  if Percent <= 0.002 then put 165 into Rate
  else if Percent <= 0.005 then put 144 into Rate
  else if Percent <= 0.01 then put 118 into Rate
  else if Percent <= 0.02 then put 98 into Rate
  else if Percent <= 0.05 then put 78 into Rate
  else if Percent <= 0.1 then put 52 into Rate
  else if Percent <= 0.2 then put 35 into Rate
  else if Percent <= 0.5 then put 21 into Rate
  else if Percent <= 1.0 then put 10.6 into Rate
  else if Percent <= 2.0 then put 6 into Rate
  else put 2.9 into Rate
 else if rainR  ion="F" then
  if Perce  . <= 0.002 then put 66 into Rate
  else if Percent <= 0.005 then put 51 into Rate
  else if Percent <= 0.01 then put 34 into Rate
  else if Percent <= 0.02 then put 23 into Rate
  else if Percent <= 0.05 then put 15 into Rate
  else if Percent <= 0.1 then put 8.3 into Rate
  else if Percent <= 0.2 then put 5.2 into Rate
  else if Percent <= 0.5 then put 3.1 into Rate
  else if Percent <= 1.0 then put 1.4 into Rate
  else if Percent <= 2.0 then put 0.7 into Rate
  else put 0.2 into Rate
 else if rainRegion="G" then
  if Percent <= 0.002 then put 185 into Rate
  else if Percent <= 0.005 then put 157 into Rate
  else if Percent <= 0.01 then put 120.5 into Rate
  else if Percent <= 0.02 then put 94 into Rate
  else if Percent <= 0.05 then put 72 into Rate
  else if Percent <= 0.1 then put 47 into Rate
  else if Percent <= 0.2 then put 32 into Rate
  else if Percent <= 0.5 then put 21.8 into Rate
  else if Percent <= 1.0 then put 12.2 into Rate
  else if Percent <= 2.0 then put 8 into Rate
  else put 5 into Rate
 else
  if Percent <= 0.002 then put 253 into Rate
```

```
    else if Percent <= 0.005 then put 220.5 into Rate
    else if Percent <= 0.01 then put 178 into Rate
    else if Percent <= 0.02 then put 147 into Rate
    else if Percent <= 0.05 then put 119 into Rate
    else if Percent <= 0.1 then put 86.5 into Rate
    else if Percent <= 0.2 then put 64 into Rate
    else if Percent <= 0.5 then put 43.5 into Rate
    else if Percent <= 1.0 then put 22.5 into Rate
    else if Percent <= 2.0 then put 12 into Rate
    else put 5.2 into Rate
  end if
  return Rate
end FindRate
-- -- -- -- -- --
function FindRainAttenuation Glat,El,Freq,Case,Rate,Percent,Region
  if Freq < 8.5 then
    put zero into atten
  else if Rate is zero then
    put zero into atten
  else
    put calculate0Cisotherm(Glat,Case) into H
    put El/57.29578 into E
    if freq>=2.9 and freq<54 then put (4.21*(10^(-5)))*(freq^2.42) into a
    else put (4.09*(10^(-2)))*(freq^.699) into a
    if freq>=8.5 and freq<25 then put 1.41*(freq^(-.0779)) into b
    else put 2.63*(freq^(-.272)) into b
    if E<.1745329 then  -- <10° in radians
      put 8500*sin(E) into it
      put sqrt(8500*8500*sin(E)*sin(E)+(17000*H)+(H*H))-it into L
      put cos(E)*L/(8500+H) into it
      put asin(it) into phi
      put 8500*phi into bigD
    else
      put H*tan(E) into bigD
      put bigD/cos(E) into L
    end if
    put 3.8-(.6*ln(Rate)) into d
    put 2.3*(Rate^(-.17)) into x
    put .026-(.03*ln(Rate)) into v
    put ln(x*exp(v*d))/d into u
    put a*(Rate^b)*L/bigD into it
    if bigD>=0 and bigD<=d then
      put it*expl(u*b*bigD)/(u*b) into atten
    else if d<=bigD and bigD<=22.5 then
      put expl(u*b*d)/(u*b) into product1
      put (x^b)*(exp(v*b*d))/(v*b) into product2
      put (x^b)*(exp(v*b*bigD))/(v*b) into product3
      put it*(product1-product2+product3) into atten
    else if bigD > 22.5 then
      put 22.5/bigD*Percent into Percent1
      put FindRate(Region,Percent1) into Rate1
```

```
    put 3.8-(.6*ln(Rate)) into d
    put 2.3*(Rate^(-.17)) into x
    put .026-(.03*ln(Rate)) into v
    put ln(x*exp(v*d))/d into u
    put a*(Rate^b)*L/bigD into it
    put exp1(u*b*d)/(u*b) into product1
    put (x^b)*(exp(v*b*d))/(v*b) into product2
    put (x^b)*(exp(v*b*bigD))/(v*b) into product3
    put it*(product1-product2+product3) into atten
   end if
  end if
  return atten
end FindRainAttenuation
-- -- -- -- -- --
---------------
```

APPENDIX D: CARD SCRIPTS

```
--------------
Script of Card "Stack Info"
--------------
-- -- -- -- -- --
on openCard
  global orbitPage, groundPage
  if orbitPage and groundPage is true then
    hide cd btn id 16
  else
    show cd btn id 16
  end if
end openCard
-- -- -- -- -- --
--------------
Script of Card "What You Know of Orbits"
--------------
-- -- -- -- -- --
on openCard
  global orbitPage,groundPage
  lock screen
  if orbitPage is false then
    show cd btn id 15
  else if groundPage is false then
    show cd btn id 15
  else
    hide cd btn id 15
  end if
  unlock screen
end openCard
-- -- -- -- -- --
--------------
Script of Card "Semimajor Axis Card"
--------------
-- -- -- -- -- --
on openCard
  put "Enter the orbital information then click on 'Orbital Elements'"&&¬
  "to continue." into cd fld "Description"
  show cd fld "Description"
  select text of cd fld "a"
end openCard
-- -- -- -- -- --
--------------
Script of Card "Perigee and Apogee Card"
--------------
  -- -- -- -- --
```

```
on openCard
  put "Enter the orbital information then click on 'Orbital Elements'"&&¬
  "to continue." into cd fld "Description"
  show cd fld "Description"
  select text of cd fld "pAlt"
end openCard
-- -- -- -- -- --
-----------
Script of Card "Charlie Elements Card"
-----------
-- -- -- -- -- --
on openCard
  select text of cd fld "Sat#"
end openCard
-- -- -- -- -- --
-----------
Script of Card "Geostationary Card"
-----------
-- -- -- -- -- --
on openCard
  global GeoSat,GeoSatLon,groundPage,orbitPage
  lock screen
  if groundPage is true then
    hide cd btn id 11 -- Link Info Gray
  else
    show cd btn id 11 -- Link Info Gray
  end if
  hide bg btn "Help Me"
  if GeoSat is false then
    hide cd btn "Satellite 1"
    hide cd btn "Satellite 2"
  else
    hide cd btn "Satellite 2"
  end if
  select text of cd fld "Sat Lon"
  unlock screen
end openCard
-- -- -- -- -- --
on closeCard
  global GeoSatLon,change,groundPage,r,d2r,r2d
  lock screen
  put 42164 into r
  show cd btn "Satellite 1"
  put cd fld "Sat Lon" into GeoSatLon
  if hilite of cd btn "West" is true then
    multiply GeoSatLon by -d2r
  else
    multiply GeoSatLon by d2r
  end if
  put GeoSatLon*507/(2*pi) + 256  into x
  set the location of cd btn "Satellite 1" to round(x),151
```

```
  show bg btn "Help Me"
  if change is true then
    put false into groundPage
    put false into change
  end if
  unlock screen
end closeCard
-- -- -- -- -- --
---------------
Script of Card "Orbital Elements"
---------------
-- -- -- -- -- --
on openCard
  global orbitPage
  lock screen
  put true into orbitPage
  unlock screen
end openCard
-- -- -- -- -- --
---------------
Script of Card "Ground Station"
---------------
-- -- -- -- -- --
on openCard
  global orbitPage,groundPage,GeoSat
  lock screen
  if GeoSat is true then
    -- Prepare page for Geostationary option with 2 ground stations.
    show cd fld "Geo GS 1"
    show cd fld "Geo GS 2"
    show cd fld "Ground Station Latitude 2"
    show cd fld "Ground Station Longitude 2"
    show cd fld "Antenna Elevation 2"
    show cd btn "North 2"
    show cd btn "South 2"
    show cd btn "East 2"
    show cd btn "West 2"
    show cd btn id 23 -- Rise and Set Gray
    show cd btn id 40 -- Ground View
    if orbitPage is true then
      hide cd btn id 27 -- Link Info Gray
    else
      show cd btn id 27 -- Link Info Gray
    end if
    put "Enter the latitude and longitude of your ground stations" &&¬
    "or click on 'Enter station on Map'. Also enter the desired" &&¬
    "antenna elevation." &&¬
    "Be sure to double check their latitude and" &&¬
    "longitude before continuing." into cd fld "Description"
    show cd fld "Description"
  else
```

```
    -- Prepare page for single ground station option.
    hide cd fld "Geo GS 1"
    hide cd fld "Geo GS 2"
    hide cd fld "Ground Station Latitude 2"
    hide cd fld "Ground Station Longitude 2"
    hide cd fld "Antenna Elevation 2"
    hide cd btn "North 2"
    hide cd btn "South 2"
    hide cd btn "East 2"
    hide cd btn "West 2"
    hide cd btn id 40 -- Ground View
    if orbitPage is true then
      hide cd btn id 23 -- Rise and Set Gray
      hide cd btn id 27 -- Link Info Gray
      hide cd btn id 24 -- Ground Trace Gray
    else
      show cd btn id 23 -- Rise and Set Gray
      show cd btn id 27 -- Link Info Gray
      show cd btn id 24 -- Ground Trace Gray
    end if
    put "Enter the latitude and longitude of your ground station" &&¬
    "or click on 'Enter station on Map'. Also enter the desired" &&¬
    "antenna elevation" &&¬
    "Be sure to double check the latitude and" &&¬
    "longitude before continuing." into cd fld "Description"
    show cd fld "Description"
  end if
  put true into groundPage
  select text of cd fld "Ground Station Latitude"
  unlock screen
end openCard
-- -- -- -- -- --
on closeCard
  global ant_el,Glat,Glon,timeZone,GeoSat,Glon2,Glat2,d2r,r2d,ant_el2
  global CardClose,region,regionUp,regionDown
  -- Get Ground Station Coordinates
  lock screen
  set lockMessages to true
  put cd fld "Antenna Elevation" into ant_elDeg
  put cd fld "Antenna Elevation 2" into ant_elDeg2
  put cd fld "Ground Station Latitude" into GlatDeg
  put cd fld "Ground Station Longitude" into GlonDeg
  put ant_elDeg*d2r into ant_el
  if hilite of cd btn "West" is true then
    multiply GlonDeg by -1
    put GlonDeg*d2r into Glon
    put round(-Glon/(pi/12)) into timeZone
  else
    put GlonDeg*d2r into Glon
    put -round(Glon/(pi/12)) into timeZone
  end if
```

```
if hilite of cd btn "South" is true then multiply GlatDeg by -1
put GlatDeg*d2r into Glat
go to cd "Ground Station Placement"
put PositLat(Glat) into V
put PositLon(Glon) into H
set the loc of cd btn "GS 1" to H,V
hide cd btn "GS 1"
set lockMessages to false
pu  true into CardClose
click at H,V
set lockMessages to true
put false into CardClose
show cd btn "GS 1"
put region into regionUp
put region into regionDown
go back
if GeoSat is true then
  put ant_elDeg*d2r into ant_el
  put ant_elDeg2*d2r into ant_el2
  put cd fld "Ground Station Latitude 2" into GlatDeg2
  put cd fld "Ground Station Longitude 2" into GlonDeg2
  if hilite of cd btn "West 2" is true then
    multiply GlonDeg2 by -1
    put GlonDeg2*d2r into Glon2
  else
    put GlonDeg2*d2r into Glon2
  end if
  if hilite of cd btn "South" is true then multiply GlatDeg2 by -1
  go to cd "Ground Station Placement"
  put GlatDeg2*d2r into Glat2
  put PositLat(Glat2) into V2
  put PositLon(Glon2) into H2
  set the loc of cd btn "GS 2" to H2,V2
  hide cd btn "GS 2"
  set lockMessages to false
  put true into CardClose
  click at H2,V2
  set lockMessages to true
  put false into CardClose
  show cd btn "GS 2"
  put region into regionDown
  go back
 end if
 unlock screen
 set lockMessages to false
end closeCard
-- -- -- -- -- --
-------------
Script of Card "Rise and Set"
-------------
-- -- -- -- -- --
```

```
on openCard
  global hourRequest,period,orbitsDay,numOrbits
  lock screen
  put hourRequest into TB
  convert TB to short time
  put timeChange(TB) && "Zulu" into line 2 of cd fld "Time to Begin"
  put period into TP
  convert TP to short time
  put timeChange(TP) && "HH:MM" into line 2 of cd fld "Period"
  set numberFormat to "0.##"
  put (86400/period) into numOrbits
  put numOrbits into line 2 of cd fld "Orbits"
  put 1 into cd fld "Begin"
  put 1 into cd fld "End"
  unlock screen
  select text of cd fld "Begin"
end openCard
-- -- -- -- -- -- --
-------------
Script of Card "Ground Station Placement"
-------------
-- -- -- -- -- -- --
on openCard
  global GeoSat,GD2
  if GeoSat is false then
    hide cd btn "GS 2"
    hide cd btn "Second Ground Site"
  else if GeoSat is true then
    show cd btn "GS 2"
    show cd btn "Second Ground Site"
  end if
  put false into GD2
end openCard
-- -- -- -- -- -- --
on mouseUp
  global ant_el,Glat,Glon,timeZone,Glat2,Glon2,GeoSat,GD2,d2r,r2d,TIV
  global CardClose
  if CardClose is true then
    pass mouseUp
  else
    if GeoSat is true then
      show cd btn "GS 2"
      show cd btn "Second Ground Site"
    end if
    if the mouseH > 489 or the mouseH < 22 then
      answer "Clicked off the map! Try again."
      pass mouseUp
    end if
    if the mouseV > 312 or the mouseV < 0 then
      answer "Clicked off the map! Try again."
      pass mouseUp
```

```
end if
-- Get Ground Station Coordinates
if GD2 is false then
  set the loc of cd btn "GS 1" to the clickLoc
else if GD2 is true then
  set the loc of cd btn "GS 2" to the clickLoc
  show cd btn "GS 2"
end if
lock screen
put the mouseH into H
put the mouseV into V
-- since latitudes are distorted by the conformal mercator projection,
-- conversion of the vertical mouse click location to a latitude on the
-- map requires multiplication by a correcting factor which varies based
-- on the latitude
if GD2 is false then
  put Lat(V) into Glat
  put (H - 254.5)*(2*pi)/467 into Glon
  put Glon*r2d into GlonDeg
  put Glat into GlatDeg
  multiply Glat by d2r
  set lockMessages to true
  go to cd "Ground Station"
  set numberFormat to "0.##"
  if Glon < 0 then
    multiply GlonDeg by -1
    put GlonDeg into cd fld "Ground Station Longitude"
    set hilite of cd btn "West" to true
    set hilite of cd btn "East" to false
    multiply GlonDeg by -1
    put round(-Glon/(pi/12)) into timeZone
  else
    put GlonDeg into cd fld "Ground Station Longitude"
    set hilite of cd btn "West" to false
    set hilite of cd btn "East" to true
    put -round(Glon/(pi/12)) into timeZone
  end if
  if Glat < 0 then
    multiply GlatDeg by -1
    put GlatDeg into cd fld "Ground Station Latitude"
    set hilite of cd btn "South" to true
    set hilite of cd btn "North" to false
  else
    put GlatDeg into cd fld "Ground Station Latitude"
    set hilite of cd btn "South" to false
    set hilite of cd btn "North" to true
  end if
  if GeoSat is true then
    go back
    set lockMessages to false
  end if
```

```
    put false into TIV
   else if GD2 is true then
    Put Lat(V) into Glat2
    put (H - 254.5)*(2*pi) 467 into Glon2
    put Glon2*r2d into GlonDeg2
    put Glat2 into GlatDeg2
    multiply Glat2 by d2r
    set lockMessages to true
    go to cd "Ground Station"
    set numberFormat to "0.##"
    if Glon2 < 0 then
     multiply GlonDeg2 by -1
     put GlonDeg2 into cd fld "Ground Station Longitude 2"
     set hilite of cd btn "West 2" to true
     set hilite of cd btn "East 2" to false
    else
     put GlonDeg2 into cd fld "Ground Station Longitude 2"
     set hilite of cd btn "West 2" to false
     set hilite of cd btn "East 2" to true
    end if
    if Glat2 < 0 then
     multiply GlatDeg2 by -1
     put GlatDeg2 into cd fld "Ground Station Latitude 2"
     set hilite of cd btn "South 2" to true
     set hilite of cd btn "North 2" to false
    else
     put GlatDeg2 into cd fld "Ground Station Latitude 2"
     set hilite of cd btn "South 2" to false
     set hilite of cd btn "North 2" to true
    end if
   end if
   set lockMessages to false
   unlock Screen
  end if
end mouseUp
-- -- -- -- -- --
---------------
Script of Card "Link Info"
---------------
-- -- -- -- -- --
on openCard
  global GeoSat
  lock screen
  set hilite of cd btn "Uplink EIRP Unknown" to false
  set hilite of cd btn "Satellite G/T Unknown" to false
  set hilite of cd btn "Satellite EIRP Unknown" to false
  set hilite of cd btn "Downlink G/T Unknown" to false
  if GeoSat is false then
   show cd btn "Hide Downlink"
  else
   hide cd btn "Hide Downlink"
```

```
  end if
  put "Enter the communications system parameters. If they are" &&¬
  "unknown then click on the button below the selection."¬
  into cd fld "Description"
  show cd fld "Description"
  unlock screen
end openCard
-- -- -- -- -- -- --
on closeCard
  global EIRPUp,EIRPDown,GTUp,GTDown
  if cd fld "Uplink EIRP" is not a number then
    answer "Invalid EIRP! Try again."
    pass closeCard
  else if cd fld "Sat 1 EIRP" is not a number then
    answer "Invalid EIRP! Try again."
    pass closeCard
  else if cd fld "Sat 1 G/T" is not a number then
    answer "Invalid G/T! Try again."
    pass closeCard
  else if cd fld "Downlink G/T" is not a number then
    answer "Invalid G/T! Try again."
    pass closeCard
  end if
  put cd fld "Uplink EIRP" into EIRPUp
  put cd fld "Sat 1 G/T" into GTUp
  put cd fld "Sat 1 EIRP" into EIRPDown
  put cd fld "Downlink G/T" into GTDown
end closeCard
-- -- -- -- -- -- --
-------------
Script of Card "Link Frequency & Access Type"
-------------
-- -- -- -- -- -- --
on openCard
  global commPage,access,GeoSat
  lock screen
  if GeoSat is true then
    show cd fld "Access Label"
    show cd btn "FDMA"
    show cd btn "TDMA"
    if commPage is false then
      set hilite of cd btn "FDMA" to false
      set hilite of cd btn "TDMA" to true
      put "TDMA" into access
    end if
    put "Enter the uplink and downlink frequencies and select the" &&¬
    "access type." into cd fld "Description"
    show cd fld "Description"
  else
    hide cd fld "Access Label"
    hide cd btn "FDMA"
```

```
    hide cd btn "TDMA"
    put "Enter the uplink and downlink frequencies."¬
    into cd fld "Description"
    show cd fld "Description"
  end if
  select text of cd fld "Uplink Freq"
  put true into commPage
  unlock screen
end openCard
-- -- -- -- -- -- --
on closeCard
  global freqUp,freqDown,waveUp,waveDown
  put cd fld "Uplink Freq" into freqUp
  put cd fld "Downlink Freq" into freqDown
  put FreqToWave(freqUp) into waveUp
  put FreqToWave(freqDown) into waveDown
end closeCard
-- -- -- -- -- -- --
-------------
Script of Card "Jamming Losses"
-------------
-- -- -- -- -- -- --
on openCard
  global JamUp,JamDown,Losses
  put true into Losses
  put false into JamUp
  put false into JamDown
  set hilite of cd btn "Jam Uplink Receiver" to false
  set hilite of cd btn "Jam Downlink Receiver" to false
  put "To include jamming losses, enter the approriate jamming power" &&¬
  "for the uplink and downlink. If the power is unknown then select" &&¬
  "'Jammer Power Unknown' to find the jammer power"¬
  into cd fld "Description"
  show cd fld "Description"
end openCard
-- -- -- -- -- -- --
on closeCard
  global JamUp,JamDown,JammingUp,JammingDown
  if JamUp is true then
    put cd fld "Jammer Power" into JammingUp
  else
    put 0 into JammingUp
  end if
  if JamDown is true then
    put cd fld "Jammer Power 2" into JammingDown
  else
    put 0 into JammingDown
  end if
end closeCard
-- -- -- -- -- -- --
-------------
```

```
Script of Card "Transmission Losses"
-------------
-- -- -- -- -- --
on openCard
  global XmitLosses,Geosat,Losses
  put true into Losses
  lock screen
  set hilite of cd btn "Include Transmission Losses" to false
  put false into XmitLosses
  put "Enter the losses due to atmospheric constituents and the" &&¬
  "propagation losses due to scintillation and polarization" &&¬
  "coupling.  To include these losses into the full link budget" &&¬
  "computations click on the 'Include Transmission Losses' button."¬
  into cd fld "Description"
  show cd fld "Description"
  unlock screen
end openCard
-- -- -- -- -- --
on closeCard
  global XmitLosses,AtmLossUp,PropLossUp,AtmLossDown,PropLossDown
  global GeoSat
  if hilite of cd btn "Include Transmission Losses" is true then
    put cd fld "Atmospheric Loss Up" into AtmLossUp
    put cd fld "Propagation Loss Up" into PropLossUp
    put cd fld "Atmospheric Loss Down" into AtmLossDown
    put cd fld "Propagation Loss Down" into PropLossDown
    put true into XmitLosses
  else
    put 0 into AtmLossUp
    put 0 into PropLossUp
    put 0 into AtmLossDown
    put 0 into PropLossDown
    put false into XmitLosses
  end if
end closeCard
-- -- -- -- -- --
-------------
Script of Card "Rain Losses"
-------------
-- -- -- -- -- --
on openCard
  global RainLossesUp,RainLossesDown,GeoSat,rainRegion
  global regionUp,regionDown,PercentUp,PercentDown
  global RainAttenUp,RainAttenDown,Calc,Case,Losses
  set cursor to 4
  put true into Losses
  lock screen
  put empty into Case
  put false into Calc
  put zero into RainAttenUp
  put zero into PercentUp
```

```
 put zero into RainAttenDown
 put zero into PercentDown
 if GeoSat is false then
  set hilite of cd btn "Include Rain Losses" to false
  put false into RainLossesUp
  put false into RainLossesDown
  show cd btn "Include Rain Losses"
  hide cd btn "Include Uplink Rain Losses"
  hide cd btn "Include Downlink Rain Losses"
  hide cd btn "Display Uplink Rain Rate"
  hide cd btn "Display Downlink Rain Rate"
  put "Rain Region:" into cd fld "Region Label"
  put FindRegion(regionUp) into rainRegion
   FillRegion
  put "To include rain losses, select a surface point rain" &&¬
  "rate and then calculate the rain loss. Then select 'Include" &&¬
  "Rain Losses' prior to leaving the card." into cd fld "Description"
  show cd fld "Description"
 else
  set hilite of cd btn "Display Uplink Rain Rate" to false
  set hilite of cd btn "Display Downlink Rain Rate" to false
  set hilite of cd btn "Include Uplink Rain Losses" to false
  set hilite of cd btn "Include Downlink Rain Losses" to false
  put false into RainLossesUp
  put false into RainLossesDown
  hide cd btn "Include Rain Losses"
  show cd btn "Include Uplink Rain Losses"
  show cd btn "Include Downlink Rain Losses"
  show cd btn "Display Uplink Rain Rate"
  show cd btn "Display Downlink Rain Rate"
  put empty into cd fld "Region"
  repeat with x=4 to 15
   put empty into cd fld x
  end repeat
 end if
 repeat with x=7 to 18
  set hilite of cd btn x to false
 end repeat
 unlock screen
end OpenCard
-- -- -- -- -- --
on closeCard
 global RainAttenUp,RainAttenDown,Calc,GeoSat
 global PercentUp,PercentDown,SkyNoiseTemp
 global RainLossesUp,RainLossesDown
 if RainLossesUp is false then
  put zero into RainAttenUp
  put zero into PercentUp
 end if
 if RainLossesDown is false then
  put zero into RainAttenDown
```

```
    put zero into PercentDown
  else
    if RainAttenDown > 0 then
      put num(RainAttenDown) into loss
      put 273*(1 - 1/loss) into SkyNoiseTemp
    else
      put zero into SkyNoiseTemp
    end if
  end if
  if Calc is false then
    put zero into RainAttenUp
    put zero into RainAttenDown
    put zero into PercentUp
    put zero into PercentDown
  end if
end closeCard
-- -- -- -- -- -- --
-----------------
Script of Card "EIRP Parameters"
-----------------
-- -- -- -- -- -- --
on openCard
  global groundUplink,XmitType,GeoSat
  lock screen
  put true into groundUplink
  set hilite of cd btn "Transmitter Power Unknown" to false
  set hilite of cd btn "Antenna Gain Unknown" to false
  put "Enter the transmitter power and antenna gain and be" &&¬
  "sure to select the correct units!. If these values are" &&¬
  "unknown the click on the button below the selection."¬
  into cd fld "Description"
  show cd fld "Description"
  if GeoSat is true then
    if XmitType is "Satellite" then
      put "Downlink EIRP Parameters" into line 2 of cd fld 1
      show cd fld "InputBO Label"
      show cd fld "InputBO"
      hide cd fld "Label"
      hide cd fld "Ant Pointing Loss"
      hide cd fld "Loss to Motion"
      put "Satellite Transmitter Output Backoff (dB):"¬
      into cd fld "OutputBO Label"
    else
      put "Uplink EIRP Parameters" into line 2 of cd fld 1
      hide cd fld "InputBO Label"
      hide cd fld "InputBO"
      show cd fld "Label"
      show cd fld "Ant Pointing Loss"
      show cd fld "Loss to Motion"
      put "Ground Transmitter Output Backoff (dB):"¬
      into cd fld "OutputBO Label"
```

```
   end if
  else
   if XmitType is "Satellite" then
    hide cd fld "Label"
    hide cd fld "Ant Pointing Loss"
    hide cd fld "Loss to Motion"
    put "Downlink EIRP Parameters" into line 2 of cd fld 1
    put "Satellite Transmitter Output Backoff (dB):"¬
    into cd fld "OutputBO Label"
   else
    show cd fld "Label"
    show cd fld "Ant Pointing Loss"
    show cd fld "Loss to Motion"
    put "Uplink EIRP Parameters" into line 2 of cd fld 1
    put "Ground Transmitter Output Backoff (dB):"¬
    into cd fld "OutputBO Label"
   end if
   hide cd fld "InputBO Label"
   hide cd fld "InputBO"
  end if
  unlock Screen
  select text of cd fld "Xmit Power"
end openCard
-- -- -- -- -- --
---------------
Script of Card "G/T Parameters"
---------------
-- -- -- -- -- --
on openCard
  global satUplink,RcvrType,GeoSat
  lock screen
  put true into satUplink
  set hilite of cd btn "System Noise Temperature Unknown" to false
  set hilite of cd btn "Antenna Gain Unknown" to false
  put "Enter the system noise temprature and antenna gain and be" &&¬
  "sure to select the correct units!.  If these values are" &&¬
  "unknown the click on the button below the selection."¬
  into cd fld "Description"
  show cd fld "Description"
  If RcvrType is "Ground" then
    put "Downlink G/T Parameters" into line 2 of cd fld 1
    show cd fld "Label"
    show cd fld "Maint Margin"
    show cd fld "Ant Pointing Loss"
    show cd fld "Loss to Motion"
  else
    put "Uplink G/T Parameters" into line 2 of cd fld 1
    hide cd fld "Label"
    hide cd fld "Maint Margin"
    hide cd fld "Ant Pointing Loss"
    hide cd fld "Loss to Motion"
```

```
 end if
 unlock screen
 select text of cd fld "Sys Noise Temp"
end openCard
-- -- -- -- -- --
-----------
Script of Card "Transmitter Power"
-----------
-- -- -- -- -- --
on openCard
 global access,GeoSat,XmitType
 lock screen
 if XmitType is "Ground" then
  show cd fld "Line Loss Label"
  show cd fld "Line Loss"
  if GeoSat is true then
   if access is "FDMA" then
    show cd fld "Carriers Label"
    show cd fld "Carriers"
   else
    hide cd fld "Carriers Label"
    hide cd fld "Carriers"
   end if
  else
   hide cd fld "Carriers Label"
   hide cd fld "Carriers"
  end if
  put "Enter the satellites saturated power rating," &&¬
  "reserve for end-of-life loss and any feeder losses." &&¬
  "If access type is FDMA, enter number of carriers."¬
  into cd fld "Description"
  put "Uplink Transmitter Parameters" into cd fld 1
 else
  hide cd fld "Line Loss Label"
  hide cd fld "Line Loss"
  hide cd fld "Carriers Label"
  hide cd fld "Carriers"
  put "Enter the satellites saturated power rating," &&¬
  "reserve for end-of-life loss and any feeder losses."¬
  into cd fld "Description"
  put "Downlink Transmitter Parameters" into cd fld 1
 end if
 show cd fld "Description"
 unlock screen
 select text of cd fld "Saturated Power"
end openCard
-- -- -- -- -- --
-----------
Script of Card "Antenna Gain"
-----------
-- -- -- -- -- --
```

```
on openCard
 global AntType
 lock screen
 if AntType is "Satellite Down" then
  set hilite of cd btn "Downlink And Uplink Antenna Same" to false
  show cd btn "Downlink And Uplink Antenna Same"
  show cd fld "Label"
  show cd fld "Off Beam Loss"
  show cd fld "Pointing Error"
  put "Satellite Downlink Antenna Gain" into line 2 of cd fld 1
  put "Enter the antenna size, efficiency, off-center-beam loss" &&¬
  "due to satellite motion and satellite pointing error due to" &&¬
  "satellite attitude control errors. If the downlink" &&¬
  "antenna is the same as the uplink antenna, click on" &&¬
  "'Downlink And Uplink Antenna Same'." into cd fld "Description"
 else if AntType is "Ground Down" then
  set hilite of cd btn "Downlink And Uplink Antenna Same" to false
  show cd btn "Downlink And Uplink Antenna Same"
  hide cd fld "Label"
  hide cd fld "Off Beam Loss"
  hide cd fld "Pointing Error"
  put "Ground Downlink Antenna Gain" into line 2 of cd fld 1
  put "Enter the antenna size and efficiency. If the downlink" &&¬
  "antenna is the same as the uplink antenna, click on" &&¬
  "'Downlink And Uplink Antenna Same'." into cd fld "Description"
 else if AntType is "Satellite Up" then
  show cd fld "Label"
  show cd fld "Off Beam Loss"
  show cd fld "Pointing Error"
  hide cd btn "Downlink And Uplink Antenna Same"
  put "Satellite Uplink Antenna Gain" into line 2 of cd fld 1
  put "Enter the antenna size, efficiency, off-center-beam loss" &&¬
  "due to satellite motion and satellite pointing error due to" &&¬
  "satellite attitude control errors." into cd fld "Description"
 else if AntType is "Ground Up" then
  hide cd fld "Label"
  hide cd fld "Off Beam Loss"
  hide cd fld "Pointing Error"
  hide cd btn "Downlink And Uplink Antenna Same"
  put "Ground Uplink Antenna Gain" into line 2 of cd fld 1
  put "Enter the antenna size and efficiency."¬
  into cd fld "Description"
 end if
 unlock screen
 select text of cd fld "Ant Size"
end openCard
-- -- -- -- -- --
-------------
Script of Card "Receiver"
-------------
-- -- -- -- -- --
```

```
on openCard
 global RcvrType
 lock screen
 if RcvrType is "Ground" then
  put "Downlink Receiver" into line 2 of cd fld 1
 else
  put "Uplink Receiver" into line 2 of cd fld 1
 end if
 unlock screen
 select text of cd fld "Ant Noise Temp"
end openCard
-- -- -- -- -- --
-------------
Script of Card "Quick Budget"
-------------
-- -- -- -- -- --
on openCard
 global GeoSat,dBk,Losses
 lock screen
 if Losses is false then
  if GeoSat is false then
   hide cd btn "Calculate"
   show cd btn "General"
   show cd btn "Latest Time in View"
   hide cd btn "Optimum"
   hide cd btn "Worst Case"
   hide cd btn "Rise"
   hide cd btn "Set"
   set hilite of cd btn "General" to false
   set hilite of cd btn "Latest Time in View" to false
   set hilite of cd btn "Optimum" to false
   set hilite of cd btn "Worst Case" to false
   put empty into line 17 of cd fld 12
   hide cd fld "Overall C/N"
  else
   show cd btn "Calculate"
   hide cd btn "General"
   hide cd btn "Latest Time in View"
   hide cd btn "Optimum"
   hide cd btn "Worst Case"
   hide cd btn "Rise"
   hide cd btn "Set"
   set hilite of cd btn "Calculate" to false
   put "Overall Clear Sky C/N (dB):" into line 17 of cd fld 12
   show cd fld "Overall C/N"
  end if
  show cd btn id 42 -- Full Budget Grey
  show cd btn id 49 -- Jamming Losses Grey
  show cd btn id 50 -- Rain Losses Grey
  show cd btn id 51 -- Xmit Losses Grey
  put "The numbers that appear are from the last use of this card." &&¬
```

```
    "To calculate the latest link budget select from the options above."¬
    into cd fld "Description"
    show cd fld "Description"
    set numberFormat to "0.##"
    put -dBk into cd fld "dBk 1"
    put -dBk into cd fld "dBk 2"
    unlock screen
  end if
  put false into Losses
end openCard
-- -- -- -- -- --
----------
Script of Card "Noise Bandwidth"
----------
-- -- -- -- -- --
on openCard
  hide cd fld "Hide"
  put "Enter the noise bandwidth in MHz.  If the noise bandwidth" &&¬
  "is unknown then click on the 'Unknown' button."¬
  into cd fld "Description"
  show cd fld "Description"
  select text of cd fld "Noise Bandwidth"
end openCard
-- -- -- -- -- --
on closeCard
  global noiseBW,Noise
  put cd fld "Noise Bandwidth" into Bif
  put 10*log(Bif*10^6) into noiseBW
  put true into Noise
end closeCard
-- -- -- -- -- --
----------
Script of Card "Uplink Budget"
----------
-- -- -- -- -- --
on openCard
  global Glon,Glat,AzUp,ant_elUp,rangeUp,d2r,r2d,Link,GeoSat
  global freqUp,XmitPwrUp,EOLReserveUp,OutputBOUp,PathLossUp
  global WorstEIRPUP,GeoSat,XmitAntGain,PercentUp,NumCarriers
  global PointingLossUp,PointingLossSatMotionUp,PwrUp,EIRPUp
  global XmitLineLossUp,FeederLossUp,PwrUp
  global FreeSpaceLossUp,AtmLossUp,PropLossUp,RainAttenUp
  lock screen
  put freqUp into cd fld "freqUp"
  if GeoSat is true then
    put round(AzUp) & "°" into cd fld "AzUp"
  else
    if Link is "General" then
      put AzUp into cd fld "AzUp"
    else
      put round(AzUp) & "°" into cd fld "AzUp"
```

```
  end if
 end if
 put round(ant_elUp) & "°" into cd fld "ant_elUp"
 put round(rangeUp) into cd fld "rangeUp"
 set numberFormat to "0.00"
 if Glon > 0 then
  put Glon*r2d & "° E" into cd fld "Glon"
 else
  put -Glon*r2d & "° W" into cd fld "Glon"
 end if
 if Glat > 0 then
  put Glat*r2d & "° N" into cd fld "Glat"
 else
  put -Glat*r2d & "° S" into cd fld "Glat"
 end if
 put XmitPwrUp-EOLReserveUp-OutputBOUp into netpwr
 if netpwr="0.00" then put PwrUp+0 into netpwr
 put XmitPwrUp+0 into cd fld "XmitPwrUp"
 put -EOLReserveUp+0 into cd fld "EOLReserveUp"
 put -OutputBOUp+0 into cd fld "OutputBOUp"
 put -XmitLineLossUp+0 into cd fld "XmitLineLossUp"
 put -FeederLossUp+0 into cd fld "FeederLossUp"
 put XmitAntGain+0 into cd fld "XmitAntGain"
 put EIRPup+0+0 into cd fld "nomEIRP"
 put -PointingLossUp+0 into cd fld "PointingLossUp"
 put -PointingLossSatMotionUp+0 into cd fld "PointingLossSatMotionUp"
 put EIRPUp - PointingLossUp - ¬
 PointingLossSatMotionUp into WorstEIRPUP
 put WorstEIRPUP+0 into cd fld "EIRPup"
 -- put propefflossup+rainattenup into preciploss
 put -FreeSpaceLossUp+0 into cd fld "FreeSpaceLossUp"
 put -AtmLossUp+0 into cd fld "AtmLoss"
 put -PropLossUp+0 into cd fld "PropLoss"
 put -RainAttenUp+0 into cd fld "RainAttenUp"
 put FreeSpaceLossUp + AtmLossUp + PropLossUp + RainAttenUp¬
 into PathLossUp
 put -PathLossUp+0 into cd fld "PathLossUp"
 if Geosat is true then
  put "Output Back-Off For          Carriers (dB):" into ¬
  line 4 of cd fld 1
  put NumCarriers into cd fld "NumCarriers"
 else
  put "Output Back-Off (dB):" into line 4 of cd fld 1
  put empty into cd fld "NumCarriers"
 end if
 set numberFormat to "0.###"
 put PercentUp into cd fld "Percent"
 unlock screen
end openCard
-- -- -- -- -- --
-----------
```

Script of Card "Uplink Budget Continued"

```
-- -- -- -- -- --
on opencard
  global SatRcvrAntGain,SatRcvrNoiseTemp,GTUp
  global WorstCNUp,SatInputBO,dBk,noiseBW
  global PathLossUp,JamUp,upCJ,JammingUp,upCN
  global WorstEIRPUP,SatOffCenterLossUp
  global PointingErrorLossUp
  lock screen
  set numberFormat to "0.00"
  put SatRcvrAntGain into cd fld "SatRcvrAntGain"
  put -SatRcvrNoiseTemp+0 into cd fld "SatRcvrNoiseTemp"
  put GTUp into cd fld "Nom GT"
  put -SatOffCenterLossUp+0 into cd fld "SatOffCenterLoss"
  put -PointingErrorLossUp+0 into cd fld "PointingErrorLoss"
  put GTUp - SatOffCenterLossUp - PointingErrorLossUp¬
  into WorstGTUp
  put WorstGTUp+0 into cd fld "GTUp"
  put WorstEIRPUP+0 into cd fld "EIRPUp"
  put -PathLossUp+0 into cd fld "PathLossUp"
  put WorstGTUp+0 into cd fld "GTUp 2"
  put -dBk+0 into cd fld "dBk"
  put -noiseBW+0 into cd fld "noiseBW"
  put WorstEIRPUP - PathLossUp + WorstGTUp - dBk - ¬
  noiseBW into WorstCNUp
  put WorstCNUp+0 into cd fld "CNUp"
  put 1/(10^(WorstCNUp/10)) into upCN
  if JamUp is true then
    put WorstEIRPUP - PathLossUp - JammingUp into CJUp
    put 1/(10^(CJUp/10)) into upCJ
    put 10*log(1/(upCJ + upCN)) into OverallCNUp
  else
    put "N/A" into CJUp
    put zero into upCJ
    put WorstCNUp into OverallCNUp
  end if
  put JammingUp+0 into cd fld "Jam Up"
  put CJUp into cd fld "CJUp"
  put OverallCNUp into cd fld "Overall CNUp"
end opencard
-- -- -- -- -- --
```

Script of Card "DownLink Budget"

```
-- -- -- -- -- --
on openCard
  global GeoSatLink,Glon,Glat,Glon2,Glat2,r2d,d2r
  global rangeDown,SatXmitAntGain,SatInputBO,AzDown
  global freqDown,XmitPwrDown,EOLReserveDown
  global OutputBOdown,ant_elDown,PointingErrorLossDown
```

```
global NumCarriers,PwrDown,PercentDown,FeederLossDown
global FreeSpaceLossDown,AtmLossDown,RainAttenDown
global PropLossDown,PathLossDown,EIRPDown
global SatOffCenterLossDown,WorstEIRPDown
lock screen
put freqDown into cd fld "freqDown"
put round(ant_elDown) & "°" into cd fld "ant_elDown"
put round(rangeDown) into cd fld "rangeDown"
if GeoSat is true then
 put round(AzDown) & "°" into cd fld "AzDown"
 set numberFormat to "0.00"
 if Glon2 > 0 then
  put Glon2*r2d & "° E" into cd fld "Glon"
 else
  put -Glon2*r2d & "° W" into cd fld "Glon"
 end if
 if Glat2 > 0 then
  put Glat2*r2d & "° N" into cd fld "Glat"
 else
  put -Glat2*r2d & "° S" into cd fld "Glat"
 end if
 put "Satellite Input Back-Off (dB)" into line 2 of cd fld 1
 show cd fld "SatInputBO"
 put -SatInputBO+0 into cd fld "SatInputBO"
else
 if Link is "General" then
  put AzDown into cd fld "AzDown"
 else
  put round(AzDown) & "°" into cd fld "AzDown"
 end if
 set numberFormat to "0.00"
 if Glon > 0 then
  put Glon*r2d & "° E" into cd fld "Glon"
 else
  put -Glon*r2d & "° W" into cd fld "Glon"
 end if
 if Glat > 0 then
  put Glat*r2d & "° N" into cd fld "Glat"
 else
  put -Glat*r2d & "° S" into cd fld "Glat"
 end if
 put empty into line 2 of cd fld 1
 put zero into SatInputBO
 hide cd fld "SatInputBO"
end if
put XmitPwrDown+0 into cd fld "XmitPwrDown"
put -EOLReserveDown+0 into cd fld "EOLReserveDown"
put -FeederLossDown+0 into cd fld "FeederLossDown"
put SatXmitAntGain+0 into cd fld "SatXmitAntGain"
put -OutputBOdown+0 into cd fld "OutputBOdown"
put EIRPDown+0 into cd fld "effEIRP"
```

```
 put -SatOffCenterLossDown+0 into cd fld "SatOffCenterLoss"
 put -PointingErrorLossDown+0 into cd fld "PointingErrorLoss"
 put EIRPDown - SatOffCenterLossDown - PointingErrorLossDown¬
 into WorstEIRPDown
 put WorstEIRPDown + 0 into cd fld "EIRPDown"
 put -FreeSpaceLossDown+0 into cd fld "FreeSpaceLossDown"
 put -AtmLossDown+0 into cd fld "AtmLossDown"
 put -RainAttenDown+0 into cd fld "RainAttenDown"
 put -PropLossDown+0 into cd fld "PropLossDown"
 if Geosat is true then
  put "Output Back-Off For          Carriers (dB):" into ¬
  line 6 of cd fld 1
  put NumCarriers into cd fld "NumCarriers"
 else
  put "Output Back-Off (dB):" into line 6 of cd fld 1
  put empty into cd fld "NumCarriers"
 end if
 put FreeSpaceLossDown + AtmLossDown + RainAttenDown + PropLossDown¬
 into PathLossDown
 put -PathLossDown into cd fld "PathLossDown"
 set numberFormat to "0.###"
 put PercentDown into cd fld "Percent"
 unlock screen
end openCard
-- -- -- -- -- -- --
-------------
Script of Card "Downlink Budget Continued"
-------------
-- -- -- -- -- -- --
on opencard
 global PointingLossDown,RainAttenDown,GeoSat
 global MaintMarginDown,GTDown,WorstEIRPDown,PathLossDown
 global RcvrAntGain,dBk,noiseBW,upCN,JammingDown
 global Rcorrectfactordown,SkyNoiseTemp,upCJ,JamDown
 global RcvrNoiseTemp,PointingLossSatMotionDown
 lock screen
 set numberFormat to "0.00"
 if SkyNoiseTemp is empty then put zero into SkyNoiseTemp
 put SkyNoiseTemp+0 into cd fld "SkyNoiseTemp"
 put RcvrAntGain+0 into cd fld "RcvrAntGain"
 if RcvrNoiseTemp is not empty then
  put num(RcvrNoiseTemp) + SkyNoiseTemp into Temp
  put 10*log(Temp) into RcvrTemp
  put -RcvrTemp+0 into cd fld "RcvrNoiseTemp"
  put RcvrAntGain  - RcvrTemp into GT
 else
  put GTDown into GT
 end if
 put GT - PointingLossDown - MaintMarginDown - ¬
 PointingLossSatMotionDown into WorstGT
 put GT+0 into cd fld "terminalGT"
```

```
 put -PointingLossDown+0 into cd fld "PointingLossDown"
 put -MaintMarginDown+0 into cd fld "MaintMargin"
 put -PointingLossSatMotionDown+0 into cd fld ¬
 "PointingLossSatMotionDown"
 put WorstGT+0 into cd fld "GTDown"
 put WorstEIRPDown+0 into cd fld "EIRPDown"
 put -PathLossDown+0 into cd fld "PathLossDown"
 put WorstGT+0 into cd fld "GTDown 2"
 put -dBk+0 into cd fld "dBk"
 put -noiseBW+0 into cd fld "noiseBW"
 put WorstEIRPDown + WorstGT - dBk - PathLossDown - ¬
 noiseBW into WorstCNDown
 put WorstCNDown+0 into cd fld "WorstCNDown"
 put JammingDown+0 into cd fld "Jam Down"
 put 1/(10^(WorstCNDown/10)) into downCN
 if JamDown is true then
  put WorstEIRPDown - PathLossDown - JammingDown into CJDown
  put 1/(10^(CJDown/10)) into downCJ
  put 10*log(1/(downCJ + downCN)) into OverallCNDown
 else
  put "N/A" into CJDown
  put zero into downCJ
  put WorstCNDown into OverallCNDown
 end if
 put CJDown into cd fld "CJDown"
 put OverallCNDown+0 into cd fld "Overall CNDown"
 if GeoSat is true then
  put 10*log(1/(upCN + downCN + downCJ + upCJ)) into WorstCNOverall
  put WorstCNOverall+0 into cd fld "WorstCNOverall"
  show cd fld "WorstCNOverall"
  show cd fld "WorstCNOverall Label"
 else
  hide cd fld "WorstCNOverall"
  hide cd fld "WorstCNOverall Label"
 end if
 unlock screen
end opencard
-- -- -- -- -- --
---------------
Script of Card "Time Step"
---------------
-- -- -- -- -- -- -- --
on openCard
 global timeZone,timeAdjust,begin,period
 lock screen
 put the short date into cd fld "Date of View"
 put period into localPeriod
 convert localPeriod to short time
 put TimeChange(localPeriod) into cd fld "Period"
 if begin is true then
  set hilite of cd btn "LST" to true
```

```
    set hilite of cd btn "DST" to false
    set hilite of cd btn "Zulu" to false
    put timeZone into timeAdjust
    put the time into localTime
    put TimeChange(localTime) into cd fld "Time to Begin"
    put TimeChange(localPeriod) into cd fld "View"
  end if
  put "The 'Viewing Time' is the total time that the ground trace" &&¬
  "will run. The 'Date of View' and 'Time to begin View' will" &&¬
  "determine the starting point for the ground trace. The 'Time Step'" &&¬
  "sets the interval between satellite movements. When modifying" &&¬
  "times ensure the entry is in HH:MM format. Dont forget the colon!" &&¬
  "Ensure the date is in MM/DD/YY format." into cd fld "Description"
  show cd fld "Description"
  unlock screen
end openCard
-- -- -- -- -- -- -- --
on closeCard
  global view, period, step, dt, GHAdeg, hourRequest,timeAdjust
  put 3029572800 into JDOsec
  put cd fld "Date of View" into dateRequest
  convert dateRequest to seconds
  put char 1 to 2 of cd fld "Time to Begin" into HH
  put char 4 to 5 of cd fld "Time to Begin" into MM
  put HH + timeAdjust + (MM/60) into UT
  put UT * 3600 into hourRequest
  add dateRequest to hourRequest
  put ((dateRequest - JDOsec)/(24*3600)) into Jday
  put 100.4602346 + 0.985647348 * Jday + 15.041068 * UT into GHAlong
  put (GHAlong/360 - trunc(GHAlong/360)) * 360 into GHAdeg
  If GHAdeg < 0 then add 360 to GHAdeg
  if cd fld "View" is empty then
    put period into view
  else
    put char 4 to 5 of line 1 of cd fld "View" into it
    put 60*it into MM
    put char 1 to 2 of line 1 of cd fld "View" into it
    put 3600*it into HH
    put HH + MM into view
  end if
  if dt = empty then put 180 into dt
  if step = empty then
    put "3.0 Minute" into step
    set hilite of cd btn "3.0 Minute" to true
    set the hilite of card button "6.0 Minute" to false
    set the hilite of card button "9.0 Minute" to false
    set the hilite of card button "1.5 Minute" to false
    set the hilite of card button "15 Minute" to false
  end if
end closeCard
-- -- -- -- -- -- -- --
```

```
--------------
Script of Card "Ground Trace"
--------------
-- -- -- -- -- --
on openCard
 global hr,min,sec,orbitPage,groundPage,begin,GHAdeg,Map
 global maxLon,minLon,maxLat,minLat,aLon,bLon,aLat,bLat,swath
 global plotAll
 lock screen
 if begin is true then
  set the hilite of card button "North America" to false
  set the hilite of card button "South America" to false
  set the hilite of card button "Europe" to false
  set the hilite of card button "Africa" to false
  set the hilite of card button "Middle East" to false
  set the hilite of card button "Asia" to false
  set the hilite of card button "SE Asia & Australia" to false
  set the hilite of card button "North Atlantic" to false
  set the hilite of card button "South Atlantic" to false
  set the hilite of card button "Indian Ocean" to false
  set the hilite of card button "North Pacific" to false
  set the hilite of card button "South Pacific" to false
  set the hilite of card button "North Pole" to false
  set the hilite of card button "South Pole" to false
  set the hilite of card button "Global" to true
  -- Choose map for default
  put "Global Map" into Map
  -- Set Swath default
  set hilite of cd btn "Ground Swath" to false
  put false into swath
  put false into plotAll
  hide cd btn "Continuous"
  hide cd btn "Individual"
  -- Set Lat/Lon limits
  put pi into maxLon
  put -pi into minLon
  put (pi/2) into maxLat
  put -(pi/2) into minLat
  -- Calc scale parameters
  put 511/2 into aLon
  put 507/(2*pi) into bLon
  put 301/2 into aLat
  put -255/pi into bLat
  put false into begin
 end if
 put GHAdeg into cd fld "GHA"
 put "Select a map for view and if required select 'Ground Swath'" &&¬
 "to display the area in the satellites view based upon the" &&¬
 "ground stations antenna elevation." into cd fld "Description"
 show cd fld "Description"
 unlock screen
```

```
end openCard
-- -- -- -- -- -- -- --
-----------
Script of Card "Global Map"
-----------
-- -- -- -- -- --
on openCard
 show bg btn "Ground Trace"
 show bg btn "Rewind"
 show bg btn "Print Card"
 show bg fld "Time Step Label"
 show bg fld "Time Step"
 show bg fld "Time Label"
 show bg fld "Time"
end openCard
-- -- -- -- -- --
-----------
Script of Card "Geo Global"
-----------
-- -- -- -- -- --
on openCard
 global Glon,Glat,Glon2,Glat2,GeoSatLon,lat,lon,d2r,r2d
 global z,r,Re,ant_el,ant_el2,t1,t2,dphi,e1,e2,e3
 global n1,n2,n3,p1,p2,p3,earth_e,cEl,sEl,ant_elUp,ant_elDown
 global lonV,latV,aLon,aLat,bLon,bLat,cLon,cLat,oldXv,oldYv
 global xS,yS,gxS,gyS,xV,yV,Map,PlotType,orbitPage
 global rangeUp,rangeDown,AzUp,AzDown,groundPage
 if groundPage is true then
  hide cd btn id 11 -- Link Info Gray
 else
  show cd btn id 11 -- Link Info Gray
 end if
 put true into orbitPage
 set cursor to busy
 put "The field of view for this satellite is based upon" &&¬
 "the greatest antenna elavation of the two ground stations." ¬
 into cd fld "Description"
 show cd fld "Description"
 put ant_el into ant_el1
 if ant_el2 > ant_el then
  put ant_el2 into ant_el
 end if
 -- Calc scale parameters
 hide bg btn "Satellite 2"
 put "Global Map" into Map
 put 511/2 into aLon
 put 507/(2*pi) into bLon
 put 301/2 into aLat
 put -255/pi into bLat
 put aLon + bLon*Glon into gxS1
 put aLat + bLat*Glat into gyS1
```

```
put aLon + bLon*GeoSatLon into xSat
put aLon + bLon*Glon2 into gxS2
put aLat + bLat*Glat2 into gyS2
set the loc of bg btn "Ground Uplink" to round(gxS1),round(gyS1)
set the loc of bg btn "Ground Downlink" to round(gxS2),round(gyS2)
set the loc of bg btn "Satellite 1" to round(xSat),151
put 0 into lat
put GeoSatLon into lon
choose brush tool
set brush to 32
set pattern to 12
Swath_Width -- Handler in stack script.
repeat with j = 0 to 30
  put j*dphi into phi
  put cos(phi) into cphi
  put sin(phi) into sphi
  put t1*p1 + t2*(cphi*n1  + sphi*e1) into xView
  put t1*p2 + t2*(cphi*n2 + sphi*e2) into yView
  put t1*p3 + t2*(cphi*n3 + sphi*e3) into zView
  put aSin(zView/r) into latV
  put aTan2(xView,yView) into lonV
  put "Field of View" into PlotType
  PlotMap -- Handler in stack script.
  if j = 0 then
    put xV into oldXv
    put yV into oldYv
  end if
  if abs(oldXv - xV) < 250 then
   drag from round(oldXv),round(oldYv) to round(xV),round(yV)
  else
    Interpolate
  end if
  put xV into oldXv
  put yV into oldYv
end repeat
choose browse tool
put r*cos(GeoSatLon) into ox
put r*sin(GeoSatLon) into oy
put zero into oz
put GeodedicLat(Glat) into GeoLat
put GeodedicLat(Glat2) into GeoLat2
put GeodedicR(GeoLat) into R_Oblong
put GeodedicR(GeoLat2) into R_Oblong2
put cos(GeoLat)*cos(Glon) into gx
put cos(GeoLat)*sin(Glon) into gy
put sin(GeoLat) into gz
put ox*gx + oy*gy + oz*gz into r_on_R
put cos(GeoLat2)*cos(Glon2) into gx2
put cos(GeoLat2)*sin(Glon2) into gy2
put sin(GeoLat2) into gz2
put ox*gx2 + oy*gy2 + oz*gz2 into r_on_R_2
```

```
if r_on_R >= R_Oblong then
  put asin(r_on_R/r) into theoretical_el
  put atan((sin(theoretical_el) - R_Oblong r)/¬
  cos(theoretical_el)) into true_el
  if true_el >= ant_el1 then
    put SlantRange(r,R_Oblong,true_el) into rangeUp
    put Glon - GeoSatLon into del_lon
    put Azimuth (del_lon,Glat,GeoSatLon) into AzUp
    put true_el*r2d into ant_elUp
  else
    answer "The uplink station is not in view of the Satellite!" &&¬
    "Either move the ground station, move the satellite or" &&¬
    "modify the antenna elevation."
    put "N/A" into ant_elUp
    put "N/A" into AzUp
    put false into orbitPage
    show cd btn id 11 -- Link Info Gray
  end if
else
  answer "The uplink station is not in view of the Satellite!" &&¬
  "Either move the ground station or move the satellite."
  put "N/A" into ant_elUp
  put "N/A" into AzUp
  put false into orbitPage
  show cd btn id 11 -- Link Info Gray
end if
if r_on_R_2 >= R_Oblong2 then
  put asin(r_on_R_2/r) into theoretical_el2
  put atan((sin(theoretical_el2) - R_Oblong2/r)/¬
  cos(theoretical_el2)) into true_el2
  if true_el2 >= ant_el2 then
    put SlantRange(r,R_Oblong2,true_el2) into rangeDown
    put Glon2 - GeoSatLon into del_lon2
    put Azimuth (del_lon2,Glat2,GeoSatLon) into AzDown
    put true_el2*r2d into ant_elDown
  else
    answer "The downlink station is not in view of the Satellite!" &&¬
    "Either move the ground station, move the satellite or" &&¬
    "modify the antenna elevation."
    put "N/A" into ant_elDown
    put "N/A" into AzDown
    put false into orbitPage
    show cd btn id 11 -- Link Info Gray
  end if
else
  answer "The downlink station is not in view of the Satellite!" &&¬
  "Either move the ground station or move the satellite."
  put "N/A" into ant_elDown
  put "N/A" into AzDown
  put false into orbitPage
  show cd btn id 11 -- Link Info Gray
```

```
  end if
  hide cd fld "Description"
  set numberFormat to "0.##"
  put AzUp into cd fld "Azimuth Up"
  put ant_elUp into cd fld "Elevation Up"
  put AzDown into cd fld "Azimuth Down"
  put ant_elDown into cd fld "Elevation Down"
end openCard
-- -- -- -- -- -- --
on closeCard
  choose select tool
  doMenu "Revert"
  choose browse tool
end closeCard
-- -- -- -- -- -- --
-------------
```

APPENDIX E: MAJOR BUTTON SCRIPTS

Inclusion of all of the button scripts was prohibitive. The first eight scripts listed represent a generalized version of the major navigation buttons. The remainder are significant enough that their inclusion was necessary. Wherever possible, scripts of similar buttons on a specific card have been normalized.

```
-------------
Script of Button "< Button Name >" of < Card or Background > "< Card or Background Name >"
-------------
-- -- -- -- -- --
on mouseUp
 global Error
 if Error is true then
  answer "You have an invalid entry! Try again."
  pass mouseUp
 else
  go to cd "< Card Name >"
 end if
end mouseUp
-- -- -- -- -- --
-------------
Script of  Button "Print Card" of < Card or Background "< Card or Background Name >"
-------------
-- -- -- -- -- --
on mouseUp
 doMenu "Print Card"
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "< Button Name >" of Card "< Card Name >"
-------------
-- -- -- -- -- --
on mouseUp
 answer "Not an option from this card."
end mouseUp
-- -- -- -- -- --
-------------
Script of Button "Help Me" of < Card or Background "< Card or Background Name >l"
-------------
-- -- -- -- -- --
on mouseUp
 global Goal
 put the short name of this cd into Goal
 go to cd "Help" && Goal
end mouseUp
-- -- -- -- -- --
-------------
```

Script of Background Button "Return" of Background "Help"

```
-- -- -- -- -- --
on mouseUp
  global Goal
  visual effect Shrink to top
  go to cd Goal
end mouseUp
-- -- -- -- -- --
```

Script of Button "< Button Name >" of Card "< Help Card Name >"

```
-- -- -- -- -- --
on mouseUp
  visual effect Shrink to top
  go to "< Card Name >"
end mouseUp
-- -- -- -- -- --
```

Script of Background Button "Rewind" of Background "< Map Background Name >"

```
-- -- -- -- -- --
on mouseUp
  global Map
  if the short name of prev cd = map then
    go prev
  else go to cd "Ground Trace"
end mouseUp
-- -- -- -- -- --
```

Script of Background Button "Forward" of Background "< Map Background Name >"

```
-- -- -- -- -- --
on mouseUp
  global Map
  if the short name of prev cd = map then
    go next
  else go to cd "Ground Trace"
end mouseUp
-- -- -- -- -- --
```

Script of Card Button "Semimajor Axis" of Card "What You Know of Orbits"

```
-- -- -- -- -- --
on mouseUp
  global GeoSat,commPage,groundPage,begin,orbitPage,TIV,Noise
  put false into commPage
  put false into orbitPage
  put false into groundPage
  put false into TIV
  put true into begin
```

```
  put false into GeoSat
  put false into Noise
  set hilite of me to true
  set the hilite of card button "Perigee and Apogee" to false
  set the hilite of card button "Charlie Elements" to false
  set the hilite of card button "Geostationary" to false
  go to card "Semimajor Axis Card"
end mouseUp
-- -- -- -- -- -- --
```

Script of Card Button "Perigee and Apogee" of Card "What You Know of Orbits"

```
-- -- -- -- -- -- --
on mouseUp
  global GeoSat,commPage,groundPage,begin,orbitPage,TIV,Noise
  put false into commPage
  put false into orbitPage
  put false into groundPage
  put false into TIV
  put true into begin
  put false into GeoSat
  put false into Noise
  set hilite of me to true
  set the hilite of card button "Semimajor Axis" to false
  set the hilite of card button "Charlie Elements" to false
  set the hilite of card button "Geostationary" to false
  go to card "Perigee and Apogee Card"
end mouseUp
-- -- -- -- -- -- --
```

Script of Card Button "Charlie Elements" of Card "What You Know of Orbits"

```
-- -- -- -- -- -- --
on mouseUp
  global GeoSat,commPage,groundPage,begin,orbitPage,TIV,Noise
  put false into commPage
  put false into orbitPage
  put false into groundPage
  put false into TIV
  put true into begin
  put false into GeoSat
  put false into Noise
  set hilite of me to true
  set the hilite of card button "Semimajor Axis" to false
  set the hilite of card button "Perigee and Apogee" to false
  set the hilite of card button "Geostationary" to false
  go to card "Charlie Elements Card"
end mouseUp
-- -- -- -- -- -- --
```

Script of Card Button "Geostationary" of Card "What You Know of Orbits"

```
-------------
-- -- -- -- -- --
on mouseUp
  global GeoSat,groundPage,orbitPage,commPage,Noise
  put true into GeoSat
  put false into groundPage
  put false into orbitPage
  put false into commPage
  put false into Noise
  set hilite of me to true
  set the hilite of card button "Semimajor Axis" to false
  set the hilite of card button "Perigee and Apogee" to false
  set the hilite of card button "Charlie Elements" to false
  go to card "Geostationary Card"
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Orbital Elements" of Card "Semimajor Axis Card"
-------------
-- -- -- -- -- --
on mouseUp
  set the cursor to 4
  lock screen
  global ecc,param,Rmin,Rmax,Re,a,b,asnDeg,perDeg,incDeg,mu,hr,min,sec
  global aAlt, pAlt, period,Error
  if Error is true then
    answer "You have an invalid entry! Try again."
    pass mouseUp
  else
    put line 1 of card field "a" into a
    put line 1 of card field "ecc" into ecc
    put line 1 of card field "asnDeg" into asnDeg
    put line 1 of card field "perDeg" into perDeg
    put line 1 of card field "incDeg" into incDeg
    if a is not a number then
      answer "Invalid Semimajor Axis. Try Again!"
      put "Enter Semimajor Axis in Kilometers" into cd fld "Description"
      show cd fld "Description"
      pass mouseUp
    else if a < 6378 then
      answer "Your orbit passes through the Earth. Try Again!"
      put "Enter Semimajor Axis in Kilometers" into cd fld "Description"
      show cd fld "Description"
      pass mouseUp
    end if
    if ecc is not a number or ecc < 0 or ecc >= 1 then
      answer "Not a valid eccentricity. Try Again!"
      put "Enter the Eccentricity" into cd fld "Description"
      put "0 ≤ e < 1" into line 2 of cd fld "Description"
      show cd fld "Description"
      pass mouseUp
```

```
end if
if incDeg is not a number or incDeg < 0 or incDeg > 180 then
 answer "Not a valid inclination. Try Again!"
 put "Enter The Inclination." into cd fld "Description"
 put "0° to 180°" into line 2 of cd fld "Description"
 show cd fld "Description"
 pass mouseUp
end if
if asnDeg is not a number or asnDeg < 0 or asnDeg > 360 then
 answer "Not a valid Longitude of the Ascending Node. Try Again!"
 put "Enter The Longitude of the Ascending Node." into cd fld "Description"
 put "0° to 360° to the East" into line 2 of cd fld "Description"
 show cd fld "Description"
 pass mouseUp
end if
if perDeg is not a number or perDeg < 0 or perDeg > 360 then
 answer "Not a valid Argument of Perigee. Try Again!"
 put "Enter The Argument of Perigee" into cd fld "Description"
 put "0° to 360° to the East" into line 2 of cd fld "Description"
 show cd fld "Description"
 pass mouseUp
end if
put a*(1 - ecc) - Re into pAlt
put a*(1 + ecc) - Re into aAlt
put pAlt + Re into Rmin
if Rmin < 6378 then
 answer¬
 "Invalid eccentricity, the satellite will hit the earth. Try again"
 select text of cd fld "ecc"
 exit mouseUp
end if
put aAlt + Re into Rmax
put Rmin*(1+ecc) into param
put a*sqrt(1 - ecc*ecc) into b
put 2*pi*sqrt(a*a*a/mu) into period
put trunc(period) into intP
put intP div 3600 into hr
put (intP - 3600*hr) div 60 into min
put (intP - 3600*hr - 60*min) into sec
go to card "Orbital Elements"
set numberFormat to "0.#"
put a & " Km" into line 1 of card field "a"
set numberFormat to "0.###"
put ecc into line 1 of card field "ecc"
set numberFormat to "0.#"
put pAlt & " Km" into line 1 of card field "pAlt"
put aAlt & " Km" into line 1 of card field "aAlt"
put asnDeg & " °" into line 1 of card field "asnDeg"
put perDeg & " °" into line 1 of card field "perDeg"
put incDeg & " °" into line 1 of card field "incDeg"
set numberFormat to "0."
```

```
  if sec >= 10 then
    put hr & ":" & min & ":" & sec & " HH:MM:SS"into ¬
   line 1 of card field "Time"
  else
    put hr & ":" & min & ":" & "0" & sec & " HH:MM:SS"into ¬
   line 1 of card field "Time"
  end if
 end if
end mouseUp
-- -- -- -- -- -- --
-------------
Script of Card Button "Orbital Elements" of Card "Perigee and Apogee Card"
-------------
-- -- -- -- -- -- --
on mouseUp
 set the cursor to 4
 global ecc,param,Rmin,Rmax,Re,a,b,asnDeg,perDeg,incDeg,mu,hr,min,sec
 global aAlt, pAlt, period, Error
 if Error is true then
  answer "You have an invalid entry! Try again."
  pass mouseUp
 else
  lock screen
  put line 1 of card field "pAlt" into pAlt
  put line 1 of card field "aAlt" into aAlt
  put line 1 of card field "asnDeg" into asnDeg
  put line 1 of card field "perDeg" into perDeg
  put line 1 of card field "incDeg" into incDeg
  if pAlt > aAlt then
    put pAlt into temp
    put aAlt into pAlt
    put temp into aAlt
    put pAlt into cd fld "pAlt"
    put aAlt into cd fld "aAlt"
  end if
  if pAlt is not a number or pAlt < 0 then
   answer "Not a valid Altitude of Perigee. Try Again!"
   put "Altitude of Perigee in Kilometers" into cd fld "Description"
   show cd fld "Description"
    pass mouseUp
  end if
  if aAlt is not a number or aAlt < 0 then
   answer "Not a valid Altitude of Apogee. Try Again!"
   put "Altitude of Apogee in Kilometers." into cd fld "Description"
   show cd fld "Description"
    pass mouseUp
  end if
  if incDeg is not a number or incDeg < 0 or incDeg > 180 then
   answer "Not a valid inclination. Try Again"
   put "Enter The Inclination." into cd fld "Description"
   put "0° to 180°" into line 2 of cd fld "Description"
```

```
  show cd fld "Description"
   pass mouseUp
 end if
 if asnDeg is not a number or asnDeg < 0 or asnDeg > 360 then
  answer "Not a valid Longitude of the Ascending Node. Try Again!"
  put "Enter The Longitude of the Ascending Node." into cd fld "Description"
  put "0° to 360° to the East" into line 2 of cd fld "Description"
  show cd fld "Description"
   pass mouseUp
 end if
 if perDeg is not a number or perDeg < 0 or perDeg > 360 then
  answer "Not a valid Argument of Perigee. Try Again!"
  put "Enter The Argument of Perigee" into cd fld "Description"
  put "0° to 360° to the East" into line 2 of cd fld "Description"
  show cd fld "Description"
   pass mouseUp
 end if
 put pAlt + Re into Rmin
 put aAlt + Re into Rmax
 put Rmin Rmax into ratio
 put (1 - ratio)/(1 + ratio) into ecc
 put Rmin*(1+ecc) into param
 -- r = param/(1 + ecc*cos(theta))
 put (pAlt + aAlt + 2*Re)/2 into a
 put a*sqrt(1 - ecc*ecc) into b
 put 2*pi*sqrt(a*a*a/mu) into period
 put trunc(period) into intP
 put intP div 3600 into hr
 put (intP - 3600*hr) div 60 into min
 put (intP - 3600*hr - 60*min) into sec
 go to card "Orbital Elements"
 set numberFormat to "0.#"
 put a & " Km" into line 1 of card field "a"
 set numberFormat to "0.###"
 put ecc into line 1 of card field "ecc"
 set numberFormat to "0.#"
 put pAlt & " Km" into line 1 of card field "pAlt"
 put aAlt & " Km" into line 1 of card field "aAlt"
 put asnDeg & " °" into line 1 of card field "asnDeg"
 put perDeg & " °" into line 1 of card field "perDeg"
 put incDeg & " °" into line 1 of card field "incDeg"
 set numberFormat to "0."
 if sec >= 10 then
   put hr & ":" & min & ":" & sec & " HH:MM:SS"into ¬
  line 1 of card field "Time"
 else
   put hr & ":" & min & ":" & "0" & sec & " HH:MM:SS"into ¬
  line 1 of card field "Time"
 end if
end if
end mouseUp
```

```
-- -- -- -- -- -- --
-------------
Script of Card Button "Orbital Elements" of Card "Charlie Elements Card"
-------------
-- -- -- -- -- -- --
on mouseUp
 set the cursor to 4
 global ecc,param,Rmin,Rmax,Re,a,b,asnDeg,perDeg,incDeg,mu,hr,min,sec
 global aAlt, pAlt, period, asnTime,Error
 if Error is true then
  answer "Invalid entry! Try again."
  pass mouseUp
 else
  put 806.81364522 into herg
  lock screen
  put line 1 of card field "M M Motion" into MMM
  put line 1 of card field "ecc" into ecc
  put line 1 of card field "asnC" into asnC
  put line 1 of card field "perC" into perC
  put line 1 of card field "incC" into incC
  put (mu*(herg/MMM)^2)^(1/3) into a
  put asnC*360 into asnDeg
  put perC*360 into perDeg
  put incC*360 into incDeg
  put a*(1 - ecc) - Re into pAlt
  put a*(1 + ecc) - Re into aAlt
  put pAlt + Re into Rmin
  put aAlt + Re into Rmax
  put a*sqrt(1 - ecc*ecc) into b
  put Rmin*(1+ecc) into param
  put 2*pi*sqrt(a*a*a/mu) into period
  put trunc(period) into intP
  put intP div 3600 into hr
  put (intP - 3600*hr) div 60 into min
  put (intP - 3600*hr - 60*min) into sec
  go to card "Orbital Elements"
  set numberFormat to "0.#"
  put a & " Km" into line 1 of card field "a"
  set numberFormat to "0.###"
  put ecc into line 1 of card field "ecc"
  set numberFormat to "0.#"
  put pAlt & " Km" into line 1 of card field "pAlt"
  put aAlt & " Km" into line 1 of card field "aAlt"
  put asnDeg & " °" into line 1 of card field "asnDeg"
  put perDeg & " °" into line 1 of card field "perDeg"
  put incDeg & " °" into line 1 of card field "incDeg"
  set numberFormat to "0."
  if sec >= 10 then
    put hr & ":" & min & ":" & sec & " HH:MM:SS"into ¬
   line 1 of card field "Time"
  else
```

```
      put hr & ":" & min & ":" & "0" & sec & " HH:MM:SS"into ¬
     line 1 of card field "Time"
    end if
  end if
end mouseUp
-- -- -- -- -- --
---------------
Script of Card Button "Equator" of Card "Geostationary Card"
---------------
-- -- -- -- -- --
on mouseUp
  global GeoSatLon, change
  lock screen
  put the mouseH into x
  set the location of cd btn "Satellite 1" to x,151
  show cd btn "Satellite 1"
  if x = 256 then
    put zero into GeoSatLon
    put GeoSatLon into cd fld "Sat Lon"
    set hilite of cd btn "East" to true
    set hilite of cd btn "West" to false
  else
    put (x - 256)*(2*pi)/507 into GeoSatLon
    put GeoSatLon*180/pi into lonDeg
    if lonDeg < 0 then
      set hilite of cd btn "East" to false
      set hilite of cd btn "West" to true
    else
      set hilite of cd btn "East" to true
      set hilite of cd btn "West" to false
    end if
    put round(abs(lonDeg)) into cd fld "Sat Lon"
  end if
  put true into change
  unlock screen
end mouseUp
-- -- -- -- -- --
---------------
Script of Card Button "Compute Rise and Set" of Card "Rise and Set"
---------------
-- -- -- -- -- --
on mouseUp
  global Error
  if Error is true then
    answer "You have an invalid entry! Try again."
    pass mouseUp
  else
    put "Computing, This might take a while" into msg
    show msg
    -- lock screen
    set cursor to 4
```

```
put empty into cd fld "Rise Time"
put empty into cd fld "Rise Azimuth"
put empty into cd fld "Elevation Angle"
put empty into cd fld "Set Time"
put empty into cd fld "Set Azimuth"
global ecc,param,Rmin,Rmax,Re,a,b,asnDeg,perDeg,incDeg,dt,mu
global period, GHAdeg, hourRequest,Glat,Glon,ant_el,we,d2r,r2d
global E,t,meanMotion,ex,ey,ez,vx,vy,vz,sinE,cosE,t0
global we,MaxRangeRise,MaxRangeSet,MinRange,TIV,AzRise,AzSet
global AzOpt,ElRise,ElSet,ElOpt
put true into TIV
put zero into MaxRangeRise
put zero into MaxRangeSet
put 35786 into MinRange
put sqrt(a*a*a/mu) into meanMotion
put true into first
put one into line_num
put "0,0,0,0,0" into data
put zero into ElOpt
put zero into ElRise
put zero into ElSet
put zero into AzSet
put zero into AzRise
put zero into AzOpt
put 0.081992 into earth_e
OrbitXform -- Handler in stack script.
-- Get Ground Station Coordinates
put GeodedicLat(Glat) into GeoLat
put GeodedicR(GeoLat) into R_Oblong
-- Calc orbit points
put cd fld "Begin" into begin
put cd fld "End" into theEnd
put trunc((begin - 1)*period/60) + 1 into start
put round(theEnd*period/60) into finish
repeat with k = start to finish
  add one to k
  put k*60 into orbtime
  put orbtime + t0 into t
  put orbtime + hourRequest into elapsedTime
  convert elapsedTime to short time
  Newton_Raphson -- Handler in stack script.
  -- Solution for the true anomaly
  put cos(E) into cosE
  put (cosE-ecc)/(1-ecc*cosE) into cosOrbAng
  put sqrt(1-cosOrbAng*cosOrbAng) into sinOrbAng
  if sin(E) < 0 then put -sinOrbAng into sinOrbAng
  -- Solution for the Satellites inertial coordinates
  put param/(1+ecc*cosOrbAng) into r
  put r*cosOrbAng into rp
  put r*sinOrbAng into rv
  put ex*rp + vx*rv into ox
```

```
put ey*rp + vy*rv into oy
put ez*rp + vz*rv into oz
put we*t into wet
-- Solution for the sub-satellite point
put cos(wet) into CosWet
put sin(wet) into SinWet
put ox*cosWet + oy*sinWet into xe
put -ox*sinWet + oy*cosWet into ye
put aSin(oz/r) into satLat
put aTan2(xe,ye) into satLon
-- Solution for the ground stations inertial coordinates
put Glon + wet into Gang
put cos(GeoLat)*cos(Gang) into gx
put cos(GeoLat)*sin(Gang) into gy
put sin(GeoLat) into gz
put ox*gx + oy*gy + oz*gz into r_on_R
if r_on_R >= R_Oblong then
 put asin(r_on_R/r) into theoretical_el
 put atan((sin(theoretical_el) - R_Oblong/r)/¬
 cos(theoretical_el)) into true_el
 if true_el >= ant_el then
  put SlantRange(r,R_Oblong,true_el) into range
  put Glon - satLon into del_lon
  put Azimuth (del_lon,Glat,satLat) into AZ
  if first is true then
   add one to line_num
   put range into MaxRangeRise
   put TimeChange(elapsedTime) into item 1 of data
   put Round(AZ) & "°" into item 2 of data
    put AZ into AzRise
    put false into first
    put true_el*r2d into ElRise
    put zero into ElOpt
  end if
  if true_el*r2d > ElOpt then
   put true_el*r2d into ElOpt
   put AZ into AzOpt
  end if
  put range into MaxRangeSet
  if range < MinRange then
   put range into MinRange
  end if
  put Round(ElOpt) & "°" into item 3 of data
  put TimeChange(elapsedTime) into item 4 of data
  put Round(AZ) & "°" into item 5 of data
   put AZ into AzSet
   put true_el*r2d into ElSet
 end if
else
 put true into first
 put zero into max_el
```

```
      end if
      put item 1 of data into line line_num of cd fld "Rise Time"
      put item 2 of data into line line_num of cd fld "Rise Azimuth"
      put item 3 of data into line line_num of cd fld "Elevation Angle"
      put item 4 of data into line line_num of cd fld "Set Time"
      put item 5 of data into line line_num of cd fld "Set Azimuth"
    end repeat
    hide msg
  end if
end mouseUp
-- -- -- -- -- --
----------
Script of Card Button "< Rain Region >" of Card "Ground Station Placement"
----------
-- -- -- -- -- --
on mouseUp
  global regio
  put the short name of me into region
  put region into msg
  set lockMessages to true
  pass mouseup
end mouseUp
-- -- -- -- -- --
----------
Script of Card Button "Second Ground Site" of Card "Ground Station Placement"
----------
-- -- -- -- -- --
on mouseUp
  global GD2
  put true into GD2
end mouseUp
-- -- -- -- -- --
----------
Script of Card Button "Uplink EIRP Unknown" of Card "Link Info"
----------
-- -- -- -- -- --
on mouseUp
  global XmitType,AntType
  set hilite of me to true
  put "Ground" into XmitType
  put "Ground Up" into AntType
  go cd "EIRP Parameters"
end mouseUp
-- -- -- -- -- --
----------
Script of Card Button "Downlink G/T Unknown" of Card "Link Info"
----------
-- -- -- -- -- --
on mouseDown
  global RcvrType,AntType
  put "Ground" into RcvrType
```

```
 put "Ground Down" into AntType
 set hilite of me to true
 go cd "G T Parameters"
end mouseDown
-- -- -- -- -- --
-------------
Script of Card Button "Satellite EIRP Unknown" of Card "Link Info"
-------------
-- -- -- -- -- -
on mouseUp
 global XmitType, AntType
 set hilite of me to true
 put "Satellite" into XmitType
 put "Satellite Down" into AntType
 go to cd "EIRP Parameters"
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Satellite G T Unknown" of Card "Link Info"
-------------
-- -- -- -- -- --
on mouseUp
 global RcvrType,AntType
 put "Satellite" into RcvrType
 put "Satellite Up" into AntType
 set hilite of me to true
 go to cd "G/T Parameters"
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Done" of Card "Jamming Losses"
-------------
-- -- -- -- -- --
on mouseUp
 global Jammer,waveUp,waveDown,JamUp,JamDown,Error
 if Error is true then
  answer "Invalid entry! Try again."
  pass mouseUp
 else
  lock screen
  hide me
  hide cd fld "Jammer Power Output"
  hide cd fld "Label"
  hide cd fld "Range"
  hide cd btn "Jamming in Main Beam"
  hide cd btn "Jamming at Half Beam"
  hide cd fld "Hide"
  put cd fld "Range" into range
  put cd fld "Jammer Power Output" into Power
  -- Jammer antenna is modeled as an omni-directional antenna
  -- with a gain of 1.56 dBi
```

```
    put 1.56 into gainUp
    put 1.56 into gainDown
    if hilite of cd btn "Jammer Power Unknown" is true then
     put (4*pi*range*10^3/waveUp)^2 into lossUp
      put 10*log(lossUp) into Loss
      put Power + gainUp - Loss into Jammer
      if hilite of cd btn "Jamming at Half Beam" is true then
        subtract 3 from Jammer
      end if
      show cd btn "Jammer Power Unknown"
      put Jammer into cd fld "Jammer Power"
    end if
    if hilite of cd btn "Jammer Power Unknown 2" is true then
     put (4*pi*range*10^3/waveDown)^2 into lossDown
      put 10*log(lossDown) into Loss
      put Power + gainDown - Loss into Jammer
      if hilite of cd btn "Jamming at Half Beam" is true then
        subtract 3 from Jammer
      end if
      show cd btn "Jammer Power Unknown 2"
      put Jammer into cd fld "Jammer Power 2"
    end if
    show cd fld "Jammer Power Label 2"
    show cd fld "Jammer Power 2"
    show cd fld "Jammer Power Label"
    show cd fld "Jammer Power"
    show cd btn "Jam Uplink Receiver"
    show cd btn "Jam Downlink Receiver"
    set hilite of cd btn "Jammer Power Unknown" to false
    set hilite of cd btn "Jammer Power Unknown 2" to false
    show cd btn "Jammer Power Unknown"
    show cd btn "Jammer Power Unknown 2"
    unlock screen
  end if
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "< Percent >" of Card "Rain Losses"
-------------
-- -- -- -- -- --
on mouseUp
  global PercentUp,GeoSat,Case,Rate
  global PercentDown,Direction
  lock screen
  repeat with x=7 to 18
    set hilite of cd btn x to false
  end repeat
  set hilite of me to true
  put "< Case >" into Case
  unlock screen
  put cd fld < Rate Exceeded > into Rate
```

```
  if GeoSat is false then
    put < Percent > into PercentUp
    put < Percent > into PercentDown
  else
    if Direction is "Up" then
      put< Percent > into PercentUp
    else if Direction is "Down" then
      put < Percent > into PercentDown
    end if
  end if
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Display Uplink Rain Rate" of Card "Rain Losses"
-------------
-- -- -- -- -- --
on mouseUp
  global Direction,regionUp,rainRegion
  lock screen
  set hilite of me to true
  set hilite of cd btn "Display Downlink Rain Rate" to false
  put "Up" into Direction
  put "Uplink Rain Region:" into cd fld "Region Label"
  put FindRegion(regionUp) into rainRegion
  FillRegion
  unlock screen
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Display Downlink Rain Rate" of Card "Rain Losses"
-------------
-- -- -- -- -- --
on mouseUp
  global Direction,regionDown,rainRegion
  lock screen
  set hilite of me to true
  set hilite of cd btn "Display Uplink Rain Rate" to false
  put "Down" into Direction
  put "Downlink Rain Region:" into cd fld "Region Label"
  put FindRegion(regionDown) into rainRegion
  FillRegion
  unlock Screen
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Include Uplink Rain Losses" of Card "Rain Losses"
-------------
-- -- -- -- -- --
on mouseUp
  global RainLossesUp
  if hilite of me is true then
```

```
   put true into RainLossesUp
  else
   put false into RainLossesUp
  end if
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Calculate Rain Losses" of Card "Rain Losses"
-------------
-- -- -- -- -- --
on mouseUp
 global PercentUp,Glat,Glat2,freqUp,freqDown,GeoSat
 global ant_elUp,Case,Rate,Direction
 global ant_elDown,RainAttenUp,RainAttenDown,PercentDown
 global Calc
 lock screen
 set cursor to busy
 if Case is empty then
  answer "Select a surface point rain rate"
 else
  put cd fld "Region" into Region
  put true into Calc
  if GeoSat is false then
   put FindRainAttenuation(Glat,ant_elUp,freqUp,Case,Rate,PercentUp,¬
    Region) into RainAttenUp
   put FindRainAttenuation(Glat,ant_elDown,freqDown,Case,Rate,¬
    PercentDown,Region) into RainAttenDown
  else
   if Direction is "Up" then
    put FindRainAttenuation(Glat,ant_elUp,freqUp,Case,Rate)¬
     into RainAttenUp
   else if Direction is "Down" then
    put FindRainAttenuation(Glat2,ant_elDown,freqDown,Case,Rate)¬
     into RainAttenDown
   end if
  end if
 end if
 unlock screen
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Link Info" of Card "EIRP Parameters"
-------------
-- -- -- -- -- --
on mouseUp
 global XmitType,EIRPUp,EIRPDown,PwrUp,PwrDown,XmitAntGain
 global PointingLossUp,PointingLossSatMotionUp,OutputBODown
 global SatXmitAntGain,SatInputBO,GeoSat,OutputBOUp,Error
 if Error is true then
  answer "Invalid Entry!  Try again."
  pass mouseUp
```

```
 else
  set numberFormat to "0.##"
  if XmitType is "Ground" then
   if hilite of cd btn "Watts Xmit" is true then
    put cd fld "Xmit Power" into pwr
    put 10*log(pwr) into PwrUp
   else
    put cd fld "Xmit Power" into PwrUp
   end if
   put cd fld "Ant Gain" into XmitAntGain
   put cd fld "OutputBO" into OutputBOUp
   put cd fld "Ant Pointing Loss" into PointingLossUp
   put cd fld "Loss to Motion" into PointingLossSatMotionUp
   put PwrUp + XmitAntGain - OutputBOUp into EIRPUp
   go to cd "Link Info"
   put EIRPUp into cd fld "Uplink EIRP"
  else if XmitType is "Satellite" then
   if hilite of cd btn "Watts Xmit" is true then
    put cd fld "Xmit Power" into pwr
    put 10*log(pwr) into PwrDown
   else
    put cd fld "Xmit Power" into PwrDown
   end if
   put cd fld "Ant Gain" into SatXmitAntGain
   put cd fld "OutputBO" into OutputBODown
   if GeoSat is true then
    put cd fld "InputBO" into SatInputBO
    put PwrDown + SatXmitAntGain - SatInputBO - OutputBODown¬
     into EIRPDown
   else
    put zero into SatInputBO
    put PwrDown + SatXmitAntGain - OutputBODown into EIRPDown
   end if
   go to cd "Link Info"
   put EIRPDown into cd fld "Sat 1 EIRP"
  end if
 end if
end mouseUp
-- -- -- -- -- --
----------
Script of Card Button "Link Info" of Card "G/T Parameters"
----------
-- -- -- -- -- --
on mouseUp
 global RcvrType,GTUp,GTDown,PwrUp,PwrDown
 global SatRcvrAntGain,RcvrAntGain,GeoSat,Error
 global RcvrNoiseTemp,SatRcvrNoiseTemp,MaintMarginDown
 global PointingLossDown,PointingLossSatMotionDown
 lock screen
 if Error is true then
  answer "Invalid Entry! Try again."
```

```
    pass mouseUp
  else
    set numberFormat to "0.##"
    if RcvrType is "Ground" then
      if hilite of cd btn "°K" is true then
        put cd fld "Sys Noise Temp" into noiseT
        put 10*log(noiseT) into RcvrNoiseTemp
      else
        put cd fld "Sys Noise Temp" into RcvrNoiseTemp
      end if
      put cd fld "Ant Gain" into RcvrAntGain
      put cd fld "Maint Margin" into MaintMarginDown
      put cd fld "Ant Pointing Loss" into PointingLossDown
      put cd fld "Loss to Motion" into PointingLossSatMotionDown
      put RcvrAntGain - RcvrNoiseTemp into GTDown
      go to cd "Link Info"
      put GTDown into cd fld "Downlink G/T"
    else if RcvrType is "Satellite" then
      if hilite of cd btn "°K" is true then
        put cd fld "Sys Noise Temp" into noiseT
        put 10*log(noiseT) into SatRcvrNoiseTemp
      else
        put cd fld "Sys Noise Temp" into SatRcvrNoiseTemp
      end if
      put cd fld "Ant Gain" into SatRcvrAntGain
      put SatRcvrAntGain - SatRcvrNoiseTemp into GTUp
      go to cd "Link Info"
      put GTUp into cd fld "Sat 1 G/T"
    end if
  end if
  unlock screen
end mouseUp
-- -- -- -- -- -- --
-------------
Script of Card Button "Transmitter" of Card "Transmitter Power"
-------------
-- -- -- -- -- -- --
on mouseUp
  global access,XmitPwrUp,EOLReserveUp,NumCarriers,OutputBOUp
  global FeederLossUp,XmitLineLossUp,XmitType
  global PwrUp,GeoSat,XmitPwrDown,EOLReserveDown,OutputBODown
  global FeederLossDown,PwrDown,Error
  lock screen
  if Error is true then
    answer "Invalid Entry! Try again."
    pass mouseUp
  else
    if XmitType is "Ground" then
      put 0 into PwrUp
      if hilite of cd btn "Watts" is true then
        put 10*log(cd fld "Saturated Power") into XmitPwrUp
```

```
    else
     put cd fld "Saturated Power" into XmitPwrUp
    end if
    add XmitPwrUp to PwrUp
    put cd fld "EOL Loss" into EOLReserveUp
    subtract EOLReserveUp from PwrUp
    put 0 into OutputBOUp
    subtract OutputBOUp from PwrUp
    put cd fld "Feeder Loss" into FeederLossUp
    subtract FeederLossUp from PwrUp
    put cd fld "Line Loss" into XmitLineLossUp
    subtract XmitLineLossUp from PwrUp
    if Geosat is true then
      if access is "FDMA" then
       put cd fld "Carriers" into NumCarriers
      else put 0 into NumCarriers
    else
      put 0 into NumCarriers
    end if
    set numberFormat to "0.##"
    go to cd "EIRP Parameters"
    put PwrUp into cd fld "Xmit Power"
    set hilite of cd btn "dBW Xmit" to true
    set hilite of cd btn "Watts Xmit" to false
  else if XmitType is "Satellite" then
    put 0 into PwrDown
    if hilite of cd btn "Watts" is true then
     put 10*log(cd fld "Saturated Power") into XmitPwrDown
    else
     put cd fld "Saturated Power" into XmitPwrDown
    end if
    add XmitPwrDown to PwrDown
    put cd fld "EOL Loss" into EOLReserveDown
    subtract EOLReserveDown from PwrDown
    put cd fld "Feeder Loss" into FeederLossDown
    subtract FeederLossDown from PwrDown
    go to cd "EIRP Parameters"
    set numberFormat to "0.##"
    put PwrDown into cd fld "Xmit Power"
    set hilite of cd btn "dBW Xmit" to true
    set hilite of cd btn "Watts Xmit" to false
  end if
 end if
 unlock screen
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Antenna" of Card "Antenna Gain"
-------------
-- -- -- -- -- --
on mouseUp
```

```
global AntType,XmitAntGain,SatRcvrAntGain,SatXmitAntGain
global RcvrAntGain,waveUp,waveDown,Error
global SatOffCenterLossUp,PointingErrorLossUp
global SatOffCenterLossDown,PointingErrorLossDown
lock screen
if Error is true then
 answer "Invalid Enrty!  Try again."
 pass mouseUp
else
 set numberFormat to "0.##"
 put cd fld "Ant Eff" into eff
 if hilite of cd btn "Parabolic" is true then
  if hilite of cd btn "Area (m^2)" is true then
   put cd fld "Ant Size" into area
   put sqrt(4*area/pi) into diam
  else
   put cd fld "Ant Size" into diam
  end if
  put eff*((pi*diam/waveUp)^2) into gainUp
  put eff*((pi*diam/waveDown)^2) into gainDown
 else
  put cd fld "Ant Size" into area
  put eff*4*pi*area/(waveup^2) into gainUp
  put eff*4*pi*area/(waveDown^2) into gainDown
 end if
 if AntType is "Ground Up" then
  put 10*log(gainUp) into XmitAntGain
  go to cd "EIRP Parameters"
  put XmitAntGain into cd fld "Ant Gain"
 else if AntType is "Satellite Up" then
  put 10*log(gainUp) into SatRcvrAntGain
  put cd fld "Off Beam Loss" into SatOffCenterLossUp
  put cd fld "Pointing Error" into PointingErrorLossUp
  go to cd "G/T Parameters"
  put SatRcvrAntGain into cd fld "Ant Gain"
 else if AntType is "Satellite Down" then
  put cd fld "Off Beam Loss" into SatOffCenterLossDown
  put cd fld "Pointing Error" into PointingErrorLossDown
  put 10*log(gainDown) into SatXmitAntGain
  go to cd "EIRP Parameters"
  put SatXmitAntGain into cd fld "Ant Gain"
 else if AntType is "Ground Down" then
  put 10*log(gainDown) into RcvrAntGain
  go to cd "G/T Parameters"
  put RcvrAntGain into cd fld "Ant Gain"
 end if
end if
unlock screen
end mouseUp
-- -- -- -- -- --
-------------
```

Script of Card Button "Downlink And Uplink Antenna Same" of Card "Antenna Gain"

```
-- -- -- -- -- --
on mouseUp
 global AntType,SatXmitAntGain,SatRcvrAntGain,RcvrAntGain,XmitAntGain
 global freqUp,freqDown,XmitAntGain
 global SatOffCenterLossDown,PointingErrorLossDown
 put 10*Log((freqDown freqUp)^2) into convert
 if AntType is "Satellite Down" then
  if SatRcvrAntGain is empty then
   answer "No antenna gain for the uplink has been entered." &&¬
   "Enter the antenna parameters to continue."
   pass mouseUp
  else
   put cd fld "Off Beam Loss" into SatOffCenterLossDown
   put cd fld "Pointing Error" into PointingErrorLossDown
   put SatRcvrAntGain + convert into SatXmitAntGain
   go to cd "EIRP Parameters"
   put SatXmitAntGain into cd fld "Ant Gain"
  end if
 else if AntType is "Ground Down" then
  if XmitAntGain is empty then
   answer "No antenna gain for the uplink has been entered." &&¬
   "Enter the antenna parameters to continue."
   pass mouseUp
  else
   put XmitAntGain + convert into RcvrAntGain
   go to cd "G/T Parameters"
   put RcvrAntGain into cd fld "Ant Gain"
  end if
 end if
 set hilite of me to true
end mouseUp
-- -- -- -- -- --
```

Script of Card Button "Receiver" of Card "Receiver"

```
-- -- -- -- -- --
on mouseUp
 global RcvrNoiseTemp,SatRcvrNoiseTemp,RcvrType,SkyNoiseTemp
 global Error
 lock screen
 if Error is true then
  answer "Invalid Entry! Try again."
  pass mouseUp
 else
  set numberFormat to "0.##"
  put cd fld "Ant Noise Temp" into Ta
  put cd fld "WG Loss" into l
  put num(l) into L1
  put cd fld "LNA Gain" into G2
```

```
    put cd fld "LNA Temp" into Te2
    put cd fld "DC Noise Temp" into Te3
    put cd fld "Amb Temp" into To
    put Ta/L1 + (L1 - 1)*To/L1 + Te2 + Te3/G2 into noiseT
    put 10*log(noiseT) into SysNoiseT
    if RcvrType is "Satellite" then
      put SysNoiseT into SatRcvrNoiseTemp
      go to cd "G/T Parameters"
      put SatRcvrNoiseTemp into cd fld "Sys Noise Temp"
      set hilite of cd btn "dB°K" to true
      set hilite of cd btn "°K" to false
    else if RcvrType is "Ground" then
      put SysNoiseT into RcvrNoiseTemp
      go to cd "G/T Parameters"
      put RcvrNoiseTemp into cd fld "Sys Noise Temp"
      set hilite of cd btn "dB°K" to true
      set hilite of cd btn "°K" to false
    end if
  end if
  unlock screen
end mouseUp
-- -- -- -- -- --
---------------
Script of Card Button "Optimum" of Card "Quick Budget"
---------------
-- -- -- -- -- --
on mouseUp
  global EIRPUp,EIRPDown,GTUp,GTDown,noiseBW,FreeSpaceLossDown
  global FreeSpaceLossUp,waveUp,waveDown,CNUp,dBk
  global CNDown,CNOverall,Link,pAlt,Re,ant_el,MinRange
  global rangeUp,rangeDown,AzOpt,ElOpt,AzUp,ant_elUp,AzDown,ant_elDown
  lock screen
  hide cd btn "Rise"
  hide cd btn "Set"
  set numberFormat to "0.##"
  if Link is "General" then
    put pAlt into range
    put (4*pi*range*10^3/waveUp)^2 into lossUp
    put (4*pi*range*10^3/waveDown)^2 into lossDown
    put 10*log(lossUp) into FreeSpaceLossUp
    put 10*log(lossDown) into FreeSpaceLossDown
    put EIRPUp - FreeSpaceLossUp + GTUp - dBk - noiseBW into CNUp
    put EIRPDown - FreeSpaceLossDown + GTDown - dBk - noiseBW¬
    into CNDown
    put 10^(CNUp/10) into upCN
    put 10^(CNDown/10) into downCN
    put 10*log(1/(1/upCN + 1/downCN)) into CNOverall
    put "N/A" into AzUp
    put "N/A" into AzDown
    put 90 into ant_elUp
    put 90 into ant_elDown
```

```
  else
    put MinRange into range
    put (4*pi*range*10^3/waveUp)^2 into lossUp
    put (4*pi*range*10^3/waveDown)^2 into lossDown
    put 10*log(lossUp) into FreeSpaceLossUp
    put 10*log(lossDown) into FreeSpaceLossDown
    put EIRPUp - FreeSpaceLossUp + GTUp - dBk - noiseBW into CNUp
    put EIRPDown - FreeSpaceLossDown + GTDown - dBk - noiseBW¬
    into CNDown
    put 10^(CNUp/10) into upCN
    put 10^(CNDown/10) into downCN
    put 10*log(1/(1/upCN + 1/downCN)) into CNOverall
    put AzOpt into AzUp
    put AzOpt into AzDown
    put ElOpt into ant_elUp
    put ElOpt into ant_elDown
  end if
  put range into rangeUp
  put range into rangeDown
  put rangeUp + 0 into cd fld "Slant Range Up"
  put rangeDown + 0 into cd fld "Slant Range Down"
  put -FreeSpaceLossUp + 0 into cd fld "Uplink Path Loss"
  put CNUp + 0 into cd fld "Uplink C/N"
  put -FreeSpaceLossDown + 0 into cd fld "Downlink Path Loss"
  put CNDown + 0 into cd fld "Downlink C/N"
  put CNOverall + 0 into cd fld "Overall C/N"
  set hilite of me to true
  set hilite of cd btn "Worst Case" to false
  hide cd btn id 42 -- Full Budget Grey
  hide cd btn id 49 -- Jamming Losses Grey
  hide cd btn id 50 -- Rain Losses Grey
  hide cd btn id 51 -- Xmit Losses Grey
  unlock screen
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Worst Case" of Card "Quick Budget"
-------------
-- -- -- -- -- --
on mouseUp
  global EIRPUp,EIRPDown,GTUp,GTDown,noiseBW,FreeSpaceLossDown
  global FreeSpaceLossUp,waveUp,waveDown,CNUp,dBk,AzUp,AzDown
  global CNDown,CNOverall,Link,Rmax,Re,ant_el,rangeUp,rangeDown
  global ant_elUp,ant_elDown
  lock screen
  set numberFormat to "0.#"
  if Link is "General" then
    put SlantRange(Rmax,Re,ant_el) into range
    put (4*pi*range*10^3/waveUp)^2 into lossUp
    put (4*pi*range*10^3/waveDown)^2 into lossDown
    put 10*log(lossUp) into FreeSpaceLossUp
```

```
    put 10*log(lossDown) into FreeSpaceLossDown
    put EIRPUp - FreeSpaceLossUp + GTUp - dBk - noiseBW into CNUp
    put EIRPDown - FreeSpaceLossDown + GTDown - dBk - noiseBW¬
    into CNDown
    put "N/A" into AzUp
    put "N/A" into AzDown
    put ant_el into ant_elUp
    put ant_el into ant_elDown
    put 10^(CNUp/10) into upCN
    put 10^(CNDown/10) into downCN
    put 10*log(1/(1/upCN + 1/downCN)) into CNOverall
    put range into rangeUp
    put range into rangeDown
    put rangeUp + 0 into cd fld "Slant Range Up"
    put rangeDown + 0 into cd fld "Slant Range Down"
    put -FreeSpaceLossUp + 0 into cd fld "Uplink Path Loss"
    put CNUp + 0 into cd fld "Uplink C/N"
    put -FreeSpaceLossDown + 0 into cd fld "Downlink Path Loss"
    put CNDown + 0 into cd fld "Downlink C/N"
    put CNOverall + 0 into cd fld "Overall C/N"
    hide cd btn id 42 -- Full Budget Grey
    hide cd btn id 49 -- Jamming Losses Grey
    hide cd btn id 50 -- Rain Losses Grey
    hide cd btn id 51 -- Xmit Losses Grey
  else
    show cd btn id 42 -- Full Budget Grey
    show cd btn id 49 -- Jamming Losses Grey
    show cd btn id 50 -- Rain Losses Grey
    show cd btn id 51 -- Xmit Losses Grey
    show cd btn "Rise"
    show cd btn "Set"
    set hilite of cd btn "Rise" to false
    set hilite of cd btn "Set" to false
  end if
  set hilite of me to true
  set hilite of cd btn "Optimum" to false
  unlock screen
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "General" of Card "Quick Budget"
-------------
-- -- -- -- -- --
on mouseUp
  global EIRPUp,EIRPDown,GTUp,GTDown,noiseBW,Link
  lock screen
  put "General" into Link
  show cd btn "Optimum"
  show cd btn "Worst Case"
  hide cd btn "Rise"
  hide cd btn"Set"
```

```
  put "The general case assumes the satellite is at perigee overhead" &&¬
  "for the 'Optimum' and at apogee as it comes in view for the" &&¬
  "Worst Case'." into cd fld "Description"
  show cd fld "Description"
  set hilite of me to true
  set hilite of cd btn "Latest Time In View" to false
  set hilite of cd btn "Optimum" to false
  set hilite of cd btn "Worst Case" to false
  set numberFormat to "0.##"
  put -noiseBW + 0 into cd fld "Noise Bandwidth 1"
  put -noiseBW + 0 into cd fld "Noise Bandwidth 2"
  put EIRPUp + 0 into cd fld "Uplink EIRP"
  put GTUp + 0 into cd fld "Uplink G/T"
  put EIRPDown + 0 into cd fld "Downlink EIRP"
  put GTDown + 0 into cd fld "Downlink G/T"
  show cd btn id 42 -- Full Budget Grey
  show cd btn id 49 -- Jamming Losses Grey
  show cd btn id 50 -- Rain Losses Grey
  show cd btn id 51 -- Xmit Losses Grey
  unlock screen
end mouseUp
-- -- -- -- -- --
-----------
Script of Card Button "Latest Time in View" of Card "Quick Budget"
 ----------
-- -- -- -- -- --
on mouseUp
  global EIRPUp,EIRPDown,GTUp,GTDown,noiseBW,Link,TIV
  if TIV is false then
    answer "Rise and Set calculations needed."
  else
    lock screen
    put "TIV" into Link
    put "The 'Latest Time in View' uses the actual slant ranges" &&¬
    "at satellite rise, maximum elevation and set times."¬
    into cd fld "Description"
    show cd fld "Description"
    set hilite of me to true
    show cd btn "Optimum"
    show cd btn "Worst Case"
    set hilite of cd btn "General" to false
    set hilite of cd btn "Optimum" to false
    set hilite of cd btn "Worst Case" to false
    set numberFormat to "0.##"
    put -noiseBW + 0 into cd fld "Noise Bandwidth 1"
    put -noiseBW + 0 into cd fld "Noise Bandwidth 2"
    put EIRPUp + 0 into cd fld "Uplink EIRP"
    put GTUp + 0 into cd fld "Uplink G/T"
    put EIRPDown + 0 into cd fld "Downlink EIRP"
    put GTDown + 0 into cd fld "Downlink G/T"
    show cd btn id 42 -- Full Budget Grey
```

```
    show cd btn id 49 -- Jamming Losses Grey
    show cd btn id 50 -- Rain Losses Grey
    show cd btn id 51 -- Xmit Losses Grey
    unlock screen
  end if
end mouseUp
-- -- -- -- -- --
---------------
Script of Card Button "Rise" of Card "Quick Budget"
---------------
-- -- -- -- -- --
on mouseUp
  global EIRPUp,EIRPDown,GTUp,GTDown,noiseBW,FreeSpaceLossDown
  global FreeSpaceLossUp,MaxRangeRise,waveUp,waveDown,CNUp,dBk
  global CNDown,CNOverall,Link,Rmax,Re,ant_el,rangeUp,rangeDown
  global AzRise,ElRise,ant_elUp,ant_elDown,AzUp,AzDown
  lock screen
  set numberFormat to "0.##"
  put MaxRangeRise into range
  put (4*pi*range*10^3/waveUp)^2 into lossUp
  put (4*pi*range*10^3/waveDown)^2 into lossDown
  put 10*log(lossUp) into FreeSpaceLossUp
  put 10*log(lossDown) into FreeSpaceLossDown
  put EIRPUp - FreeSpaceLossUp + GTUp - dBk - noiseBW into CNUp
  put EIRPDown - FreeSpaceLossDown + GTDown - dBk - noiseBW¬
  into CNDown
  put 10^(CNUp/10) into upCN
  put 10^(CNDown/10) into downCN
  put 10*log(1/(1/upCN + 1/downCN)) into CNOverall
  put AzRise into AzUp
  put AzRise into AzDown
  put ElRise into ant_elUp
  put ElRise into ant_elDown
  put range into rangeUp
  put range into rangeDown
  put rangeUp + 0 into cd fld "Slant Range Up"
  put rangeDown + 0 into cd fld "Slant Range Down"
  put -FreeSpaceLossUp + 0 into cd fld "Uplink Path Loss"
  put CNUp + 0 into cd fld "Uplink C/N"
  put -FreeSpaceLossDown + 0 into cd fld "Downlink Path Loss"
  put CNDown + 0 into cd fld "Downlink C/N"
  put CNOverall + 0 into cd fld "Overall C/N"
  set hilite of me to true
  set hilite of cd btn "Set" to false
  hide cd btn id 42 -- Full Budget Grey
  hide cd btn id 49 -- Jamming Losses Grey
  hide cd btn id 50 -- Rain Losses Grey
  hide cd btn id 51 -- Xmit Losses Grey
  unlock screen
end mouseUp
-- -- -- -- -- --
```

```
-------------
Script of Card Button "Set" of Card "Quick Budget"
-------------
-- -- -- -- -- --
on mouseUp
  global EIRPUp,EIRPDown,GTUp,GTDown,noiseBW,FreeSpaceLossDown
  global FreeSpaceLossUp,MaxRangeSet,waveUp,waveDown,CNUp,dBk
  global CNDown,CNOverall,Link,Rmax,Re,ant_el,AzSet,ElSet
  global AzUp,AzDown,ant_elUp,ant_elDown
  lock screen
  set numberFormat to "0.##"
  put MaxRangeSet into range
  put (4*pi*range*10^3/waveUp)^2 into lossUp
  put (4*pi*range*10^3/waveDown)^2 into lossDown
  put 10*log(lossUp) into FreeSpaceLossUp
  put 10*log(lossDown) into FreeSpaceLossDown
  put EIRPUp - FreeSpaceLossUp + GTUp - dBk - noiseBW into CNUp
  put EIRPDown - FreeSpaceLossDown + GTDown - dBk - noiseBW¬
  into CNDown
  put 10^(CNUp/10) into upCN
  put 10^(CNDown/10) into downCN
  put 10*log(1/(1/upCN + 1/downCN)) into CNOverall
  put AzSet into AzUp
  put AzSet into AzDown
  put ElSet into ant_elUp
  put ElSet into ant_elDown
  put range into rangeUp
  put range into rangeDown
  put rangeUp + 0 into cd fld "Slant Range Up"
  put rangeDown + 0 into cd fld "Slant Range Down"
  put -FreeSpaceLossUp + 0 into cd fld "Uplink Path Loss"
  put CNUp + 0 into cd fld "Uplink C/N"
  put -FreeSpaceLossDown + 0 into cd fld "Downlink Path Loss"
  put CNDown + 0 into cd fld "Downlink C/N"
  put CNOverall + 0 into cd fld "Overall C/N"
  set hilite of me to true
  set hilite of cd btn "Rise" to false
  hide cd btn id 42 -- Full Budget Grey
  hide cd btn id 49 -- Jamming Losses Grey
  hide cd btn id 50 -- Rain Losses Grey
  hide cd btn id 51 -- Xmit Losses Grey
  unlock screen
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Calculate" of Card "Quick Budget"
-------------
-- -- -- -- -- --
on mouseUp
  global EIRPUp,EIRPDown,GTUp,GTDown,noiseBW,rangeUp,rangeDown
  global FreeSpaceLossUp,FreeSpaceLossDown,waveUp,waveDown,CNUp
```

```
 global CNDown,CNOverall,dBk,noiseBW
 put (4*pi*rangeUp*10^3/waveUp)^2 into lossUp
 put (4*pi*rangeDown*10^3/waveDown)^2 into lossDown
 put 10*log(lossUp) into FreeSpaceLossUp
 put 10*log(lossDown) into FreeSpaceLossDown
 put EIRPUp - FreeSpaceLossUp + GTUp - dBk - noiseBW into CNUp
 put EIRPDown - FreeSpaceLossDown + GTDown - dBk - noiseBW¬
 into CNDown
 put 10^(CNUp/10) into upCN
 put 10^(CNDown/10) into downCN
 put 10*log(1/(1/upCN + 1/downCN)) into CNOverall
 set numberFormat to "0.##"
 put -noiseBW + 0 into cd fld "Noise Bandwidth 1"
 put -noiseBW + 0 into cd fld "Noise Bandwidth 2"
 put EIRPUp + 0 into cd fld "Uplink EIRP"
 put GTUp + 0 into cd fld "Uplink G/T"
 put EIRPDown + 0 into cd fld "Downlink EIRP"
 put GTDown + 0 into cd fld "Downlink G/T"
 put rangeUp + 0 into cd fld "Slant Range Up"
 put rangeDown + 0 into cd fld "Slant Range Down"
 put -FreeSpaceLossUp + 0 into cd fld "Uplink Path Loss"
 put CNUp + 0 into cd fld "Uplink C/N"
 put -FreeSpaceLossDown + 0 into cd fld "Downlink Path Loss"
 put CNDown + 0 into cd fld "Downlink C/N"
 put CNOverall + 0 into cd fld "Overall C/N"
 put "The general case assumes the satellite is at perigee overhead" &&¬
 "for the 'Optimum' and at apogee as it comes in view for the" &&¬
 "Worst Case'." into cd fld "Description"
 show cd fld "Description"
 hide cd btn id 42 -- Full Budget Grey
 hide cd btn id 49 -- Jamming Losses Grey
 hide cd btn id 50 -- Rain Losses Grey
 hide cd btn id 51 -- Xmit Losses Grey
end mouseUp
-- -- -- -- -- --
-------------
Script of Card Button "Done" of Card "Noise Bandwidth"
-------------
-- -- -- -- -- --
on mouseUp
 global Error
 lock screen
 if cd fld "Baseband Freq" is not a number or¬
 cd fld "Baseband Freq" < 0 then
  answer "Invalid Baseband Frequency! Try again"
  pass mouseUp
 end if
 if cd fld "FM Deviation" is not a number or¬
 cd fld "FM Deviation" < 0 then
  answer "Invalid FM Deviation! Try again."
  pass mouseUp
```

```
  end if
  put false into Error
  hide me
  hide cd fld "Baseband Freq Label"
  hide cd fld "Baseband Freq"
  hide cd fld "FM Deviation Label"
  hide cd fld "FM Deviation"
  hide cd fld "Hide"
  put cd fld "Baseband Freq"* 10^3 into Bhi
  put cd fld "FM Deviation" into dp
  set numberFormat to "0.##"
  put 2*(Bhi + dp)/10^6 into cd fld "Noise Bandwidth"
  show cd fld "Noise Bandwidth Label"
  show cd btn "Noise Bandwidth Unknown"
  set hilite of cd btn "Noise Bandwidth Unknown" to false
  show cd fld "Noise Bandwidth"
  hide cd fld "Description"
  unlock screen
  select text of cd fld "Noise Bandwidth"
end mouseUp
-- -- -- -- -- --
----------
Script of Card Button "< Time Step >" of Card "Time Step"
----------
-- -- -- -- -- --
on mouseUp
  global dt, step
  put < Time Step in Seconds > into dt
  put "< Time Step >" into step
  set hilite of me to true
  set the hilite of card button "< Other Time Step >" to false
  set the hilite of card button "< Other Time Step >" to false
  set the hilite of card button "< Other Time Step >" to false
  set the hilite of card button "< Other Time Step >" to false
  show cd fld "Description"
  put "< Time Step Recommendation >" into cd fld "Description"
end mouseUp
-- -- -- -- -- --
----------
Script of Card Button "LST" of Card "Time Step"
----------
-- -- -- -- -- --
on mouseUp
  global timeZone,timeAdjust
  set hilite of me to true
  set hilite of cd btn "DST" to false
  set hilite of cd btn "Zulu" to false
  put timeZone into timeAdjust
end mouseUp
-- -- -- -- -- -- --
----------
```

```
Script of Card Button "DST" of Card "Time Step"
-------------
-- -- -- -- -- --
on mouseUp
  global timeZone,timeAdjust
  set hilite of me to true
  set hilite of cd btn "LST" to false
  set hilite of cd btn "Zulu" to false
  put timeZone - 1 into timeAdjust
end mouseUp
-- -- -- -- -- -- --
-------------
Script of Card Button "Zulu" of Card "Time Step"
-------------
-- -- -- -- -- --
on mouseUp
  global timeZone,timeAdjust
  set hilite of me to true
  set hilite of cd btn "LST" to false
  set hilite of cd btn "DST" to false
  put 0 into timeAdjust
end mouseUp
-- -- -- -- -- -- --
-------------
Script of Card Button "Plot Track" of Card "Ground Trace"
-------------
-- -- -- -- -- --
on mouseUp
  set cursor to 4
  global ecc,param,Rmin,Rmax,Re,a,b,asnDeg,perDeg,incDeg,dt,mu
  global period, step, view, GHAdeg, hourRequest,cLat,cLon
  global aLon,bLon,aLat,bLat,maxLon,minLon,maxLat,minLat,Map
  global Glon,Glat,Swath,ant_el,plotAll,t0,E,sinE,cosE
  global d2r,r2d,ex,ey,ez,vx,vy,vz,meanMotion,PlotType
  global lon,lat,Glon,Glat,lonV,latV,xS,yS,gxS,gyS,xV,yV,sEl,cEl
  global t1,t2,dphi,e1,e2,e3,n1,n2,n3,p1,p2,p3
  global lonV,lonCk,GlonCk,lonVck,maxLonCk
  global oldXs,oldYs,oldYv,oldXv,t,r,z
  put .000072921158 56 into we
  put sqrt(a*a*a/mu) into meanMotion
  put true into first
  if swath is false then put true into plotAll
  OrbitXform -- Handler in stack script.
  -- Calc orbit points
  put round(view/dt)into noPts
  put -1 into i
  -- put 1 into kMin
  put noPts + 1 into kMax
  go to cd Map
  domenu "Copy Card"
  choose brush tool
```

```
set brush to 32
set pattern to 12
repeat with k = 1 to kMax
 add one to i
 put i*dt into orbtime
 put orbtime + t0 into t
 put orbtime + hourRequest into elapsedTime
 convert elapsedTime to short time
 Newton_Raphson -- Handler in stack script.
 put cos(E) into cosE
 put (cosE-ecc)/(1-ecc*cosE) into cosOrbAng
 put sqrt(1-cosOrbAng*cosOrbAng) into sinOrbAng
 if sin(E) < 0 then put -sinOrbAng into sinOrbAng
 put param/(1+ecc*cosOrbAng) into r
 put r*cosOrbAng into rp
 put r*sinOrbAng into rv
 put ex*rp + vx*rv into x
 put ey*rp + vy*rv into y
 put ez*rp + vz*rv into z
 put we*orbtime into wet
 put cos(wet) into CosWet
 put sin(wet) into SinWet
 put x*cosWet + y*sinWet into xe
 put -x*sinWet + y*cosWet into ye
 put aSin(z/r) into lat
 put aTan2(xe,ye) into lon
 put "Ground Site" into PlotType
 MaxLonCheck
 put "Sub Satellite" into PlotType
 MaxLonCheck -- Handler in stack script.
 if lat >= minLat and lat <= maxLat and¬
 lonCk >= minLon and lonCk <= maxLonCk then
  if Map = "Global Map" then
   doMenu "Paste Card"
   set cantDelete of this cd to false
   mark card
   put step into bg field "Time Step"
   put TimeChange(elapsedTime) & " Zulu" into bg fld "Time"
   put "Ground Site" into PlotType
   PlotMap -- Handler in stack script.
   set the loc of cd btn "GS" to round(gxS),round(gyS)
   show cd btn "GS"
   put "Sub Satellite" into PlotType
   PlotMap -- Handler in stack script.
   if i = 0 then
    put xS into oldXs
    put yS into oldYs
   end if
   if abs(oldXs - xS) < 250 then
   drag from round(oldXs),round(oldYs) to round(xS),round(yS)
   else
```

```
  Interpolate
 end if
 put xS into oldXs
 put yS into oldYs
 if plotAll is false then
  domenu "Copy Card"
 end if
 -- Plot ground swath
 if Swath is true then
  Swath_Width -- Handler in stack script.
  repeat with j = 0 to 30
    put j*dphi into phi
    put cos(phi) into cphi
    put sin(phi) into sphi
    put t1*p1 + t2*(cphi*n1  + sphi*e1) into xView
    put t1*p2 + t2*(cphi*n2 + sphi*e2) into yView
    put t1*p3 + t2*(cphi*n3 + sphi*e3) into zView
    put aSin(zView/r) into latV
    put aTan2(xView,yView) into lonV
    put "Field of View" into PlotType
    PlotMap -- Handler in stack script.
    if j = 0 then
      put xV into oldXv
      put yV into oldyv
    end if
    if abs(oldXv - xV) < 250 then
    drag from round(oldXv),round(oldYv) to round(xV),round(yV)
     else
      Interpolate
    end if
    put xV into oldXv
    put yV into oldYv
  end repeat
 end if
 if plotAll is true then
  domenu "Copy Card"
 end if
else
 doMenu "Paste Card"
 set cantDelete of this cd to false
 mark card
 put step into bg field "Time Step"
 put TimeChange(elapsedTime) & " Zulu" into bg fld "Time"
 if Glat >= minLat and Glat <= maxLat and¬
 GlonCk >= minLon and GlonCk <= maxLonCk then
  put "Ground Site" into PlotType
  PlotMap -- Handler in stack script.
  set the loc of cd btn "GS" to round(gxS),round(gyS)
  show cd btn "GS"
 end if
 put "Sub Satellite" into PlotType
```

```
PlotMap -- Handler in stack script.
if first is true then
  put xS into oldXs
  put yS into oldYs
  put false into first
end if
drag from round(oldXs),round(oldYs) to round(xS),round(yS)
put xS into oldXs
put yS into oldYs
if plotAll is false then
 domenu "Copy Card"
end if
put true into second
-- Plot ground swath
if Swath is true then
 Swath_Width -- Handler in stack script.
 repeat with j = 0 to 30
  put j*dphi into phi
  put cos(phi) into cphi
  put sin(phi) into sphi
  put t1*p1 + t2*(cphi*n1  + sphi*e1) into xView
  put t1*p2 + t2*(cphi*n2 + sphi*e2) into yView
  put t1*p3 + t2*(cphi*n3 + sphi*e3) into zView
  put aSin(zView/r) into latV
  put aTan2(xView,yView) into lonV
  put "Field of View" into PlotType
  MaxLonCheck -- Handler in stack script.
  if latV >= minLat and latV <= maxLat and¬
  lonVck >= minLon and lonVck <= maxLonCk then
    PlotMap
   if second is true then
     put xV into oldXv
     put yV into oldyv
     put false into second
   end if
   if abs(oldXv - xV) < 250 then
   drag from round(oldXv),round(oldYv) to round(xV),round(yV)
   end if
   put xV into oldXv
   put yV into oldYv
  else put true into second
 end repeat
end if
if plotAll is true then
 domenu "Copy Card"
end if
end if
else put true into first
end repeat
choose browse tool
play "Presto"
```

```
end mouseUp
-- -- -- -- -- --
-----------
Script of Card Button "Review" of Card "Ground Trace"
-----------
-- -- -- -- -- --
on mouseUp
 global Map
 go to cd Map
 repeat while marked of next card is true
  go to next card
  visual dissolve fast
 end repeat
end mouseUp
-- -- -- -- -- --
-----------
Script of Card Button "Erase" of Card "Ground Trace"
-----------
-- -- -- -- -- --
on mouseUp
 global Map
 answer "Erase all maps or just view selected?" with "All" or¬
 "View" or "Cancel"
 if it is "Cancel" then
  pass mouseUp
 else if it is "All" then
  set cursor to 4
  lock screen
  set lockMessages to true
  repeat with x = number of cards down to 1
   go to cd x
   if marked of cd x is true then
    doMenu "Delete Card"
   end if
  end repeat
  go to cd "Ground Trace"
  doMenu "Compact Stack"
  set lockMessages to false
  unlock screen
  play "Presto"
 else
  set cursor to 4
  lock screen
  set lockMessages to true
  put number of cards of bg Map into c
  repeat with x = 1 to c
   go to last cd of bg Map
   if marked of last card of bg Map is true then
    doMenu "Delete Card"
    go to last cd of bg Map
   end if
```

```
    end repeat
    go to cd "Ground Trace"
    doMenu "Compact Stack"
    set lockMessages to false
    unlock screen
    play "Presto"
  end if
end mouseUp
-- -- -- -- -- --
```

Script of Card Button "< Map Name >" of Card "Ground Trace"

```
-- -- -- -- -- --
on mouseUp
  global aLon,bLon,aLat,bLat,maxLon,minLon,maxLat,minLat,Map
  repeat with x = 5 to 19
    set hilite of cd btn x to false
  end repeat
  set hilite of me to true
  -- Choose map
  put "< Map Name >" into Map
  -- Set Lat/Lon limits
< Lat Lon Limits >
  -- Calc scale parameters
< Scale Parameters >
end mouseUp
-- -- -- -- -- --
```

Lat/Lon Limits and Scale Parameters of Card Button "Global Map" of Card "Ground Trace"

```
 -- Set Lat/Lon limits
  put pi into maxLon
  put -pi into minLon
  put (pi/2) into maxLat
  put -(pi/2) into minLat
  -- Calc scale parameters
  put 511/2 into aLon
  put 507/(2*pi) into bLon
  put 301/2 into aLat
  put -255/pi into bLat
```

Lat/Lon Limits and Scale Parameters of Card Button "North America" of Card "Ground Trace"

```
  -- Set Lat/Lon limits
  put -(pi/4) into maxLon
  put -(5*pi/6) into minLon
  put (pi 3) into maxLat
  put 0 into minLat
  put 30*(pi/180) into cLat
  put -97.5*(pi/180) into cLon
  -- Calc scale parameters
```

```
  put 255 into aLon
  put 330/(7*pi/12) into bLon
  put 129 into aLat
  put -220/(pi/3) into bLat
-------------
Lat Lon Limits and Scale Parameters of Card Button "South America" of Card "Ground Trace"
-------------
  -- Set Lat Lon limits
  put -(pi/6) into maxLon
  put -(pi/2) into minLon
  put (pi/12) into maxLat
  put -(pi/3) into minLat
  put -22.5*(pi/180) into cLat
  put -60*(pi/180) into cLon
  -- Calc scale parameters
  put 255 into aLon
  put 264/(pi/3) into bLon
  put 165 into aLat
  put -292/(5*pi/12) into bLat
-------------
Lat Lon Limits and Scale Parameters of Card Button "North Atlantic" of Card "Ground Trace"
-------------
  -- Set Lat/Lon limits
  put 0 into maxLon
  put -(pi/2) into minLon
  put (pi/3) into maxLat
  put 0 into minLat
  put 30*(pi/180) into cLat
  put -45*(pi/180) into cLon
  -- Calc scale parameters
  put 255 into aLon
  put 396/(pi/2) into bLon
  put 129 into aLat
  put -220/(pi/3) into bLat
-------------
Lat/Lon Limits and Scale Parameters of Card Button "South Atlantic" of Card "Ground Trace"
-------------
  -- Set Lat/Lon limits
  put (pi/12) into maxLon
  put -(pi/4) into minLon
  put (pi/12) into maxLat
  put -(pi/3) into minLat
  put -22.5*(pi/180) into cLat
  put -15*(pi/180) into cLon
  -- Calc scale parameters
  put 255.5 into aLon
  put 393/(pi/3) into bLon
  put 134.5 into aLat
  put -231/(5*pi/12) into bLat
-------------
Lat Lon Limits and Scale Parameters of Card Button "Europe" of Card "Ground Trace"
```

```
-------------
 -- Set Lat/Lon limits
 put (pi/4) into maxLon
 put -(pi/12) into minLon
 put (5*pi/12) into maxLat
 put (pi/6) into minLat
 put 52.5*(pi/180) into cLat
 put 15*(pi/180) into cLon
 -- Calc scale parameters
 put 255 into aLon
 put 320/(pi/3) into bLon
 put 152 into aLat
 put -266/(pi/4) into bLat
-------------
```

Lat/Lon Limits and Scale Parameters of Card Button "Africa" of Card "Ground Trace"

```
-------------
 -- Set Lat/Lon limits
 put (pi/3) into maxLon
 put -(pi/12) into minLon
 put (pi/4) into maxLat
 put -(pi/4) into minLat
 put 0*(pi/180) into cLat
 put 22.5*(pi/180) into cLon
 -- Calc scale parameters
 put 255.5 into aLon
 put 283/(5*pi/12) into bLon
 put 160.5 into aLat
 put -283/(pi/2) into bLat
-------------
```

Lat/Lon Limits and Scale Parameters of Card Button "Middle East" of Card "Ground Trace"

```
-------------
 -- Set Lat/Lon limits
 put (pi/3) into maxLon
 put (pi/6) into minLon
 put (pi/4) into maxLat
 put 0 into minLat
 put 22.5*(pi/180) into cLat
 put 45*(pi/180) into cLon
 -- Calc scale parameters
 put 255.5 into aLon
 put 267/(pi/6) into bLon
 put 168 into aLat
 put -298/(pi/4) into bLat
-------------
```

Lat/Lon Limits and Scale Parameters of Card Button "Asia" of Card "Ground Trace"

```
-------------
 -- Set Lat/Lon limits
 put (pi) into maxLon
 put (pi/4) into minLon
 put (5*pi/12) into maxLat
 put 0 into minLat
```

```
  put 37.5*(pi/180) into cLat
  put 112.5*(pi/180) into cLon
  -- Calc scale parameters
  put 255 into aLon
  put 416/(3*pi/4) into bLon
  put 134.5 into aLat
  put -231/(5*pi/12) into bLat
-------------
```

Lat Lon Limits and Scale Parameters of Card Button "Indian Ocean" of Card "Ground Trace"

```
-------------
  -- Set Lat/Lon limits
  put (2*pi/3) into maxLon
  put (pi/4) into minLon
  put (pi/6) into maxLat
  put -(pi/4) into minLat
  put -7.5*(pi/180) into cLat
  put 82.5*(pi/180) into cLon
  -- Calc scale parameters
  put 255.5 into aLon
  put 317/(5*pi/12) into bLon
  put 151 into aLat
  put -264/(5*pi/12) into bLat
-------------
```

Lat Lon Limits and Scale Parameters of Card Button "SE Asia & Australia" of Card "Ground Trace"

```
-------------
  -- Set Lat/Lon limits
  put (11*pi/12) into maxLon
  put (pi/2) into minLon
  put (pi/6) into maxLat
  put -(pi/4) into minLat
  put -7.5*(pi/180) into cLat
  put 127.5*(pi/180) into cLon
  -- Calc scale parameters
  put 255 into aLon
  put 298/(5*pi/12) into bLon
  put 167.5 into aLat
  put -297/(5*pi/12) into bLat
-------------
```

Lat Lon Limits and Scale Parametersof Card Button "North Pacific" of Card "Ground Trace"

```
-------------
  -- Set Lat/Lon limits
  put -(7*pi/12) into maxLon
  put (5*pi/6) into minLon
  put (pi/3) into maxLat
  put -(pi/6) into minLat
  put -7.5*(pi/180) into cLat
  put 82.5*(pi/180) into cLon
  put 15*(pi/180) into cLat
  put -157.5*(pi/180) + 2*pi into cLon
  -- Calc scale parameters
  put 255.5 into aLon
```

```
  put 393/(7*pi/12) into bLon
  put 144 into aLat
  put -250/(pi/2) into bLat
-------------
Lat Lon Limits and Scale Parameters of Card Button "South Pacific" of Card "Ground Trace"
-------------
  -- Set Lat Lon limits
  put -(5*pi/12) into maxLon
  put (5*pi/6) into minLon
  put (pi/6) into maxLat
  put -(pi/3) into minLat
  put -15*(pi/180) into cLat
  put -142.5*(pi/180) + 2*pi into cLon
  -- Calc scale parameters
  put 255.5 into aLon
  put 397/(3*pi/4) into bLon
  put 145.5 into aLat
  put -253/(pi/2) into bLat
-------------
Lat Lon Limits and Scale Parameters of Card Button "North Pole" of Card "Ground Trace"
-------------
  -- Set Lat Lon limits
  put pi into maxLon
  put -pi into minLon
  put (pi/2) into maxLat
  put (pi/3) into minLat
  -- Calc scale parameters
  put 511/2 into aLon
  put 507/(2*pi) into bLon
  put 301/2 into aLat
  put -255/pi into bLat
-------------
Lat Lon Limits and Scale Parameters of Card Button "South Pole" of Card "Ground Trace"
-------------
  -- Set Lat/Lon limits
  put pi into maxLon
  put -pi into minLon
  put -(pi/3) into maxLat
  put -(pi/2) into minLat
  -- Calc scale parameters
  put 511/2 into aLon
  put 507/(2*pi) into bLon
  put 301/2 into aLat
  put -255/pi into bLat
-------------
Script of Card Button "Ground Swath" of Card "Ground Trace"
-------------
-- -- -- -- -- --
on mouseUp
  global Swath,plotAll
  lock screen
```

```
 if hilite of me is true then
   put true into Swath
   show cd btn "Continuous"
   show cd btn "Individual"
   set hilite of cd btn "Continuous" to false
   set hilite of cd btn "Individual" to false
   put "Select 'Continuous' to display all the ground swaths." &&¬
   "select 'Individual' to display one ground swath per movement."¬
   into cd fld "Description"
   show cd fld "Description"
 else
   put false into swath
   hide cd btn "Continuous"
   hide cd btn "Individual"
   put false into plotAll
   hide cd fld "Description"
 end if
 unlock screen
end mouseUp
-- -- -- -- -- -- --
-------------
Script of Card Button "Continuous" of Card "Ground Trace"
-------------
-- -- -- -- -- -- --
on mouseUp
  global plotAll
  put true into plotAll
  set hilite of me to true
  set hilite of cd btn "Individual" to false
end mouseUp
-- -- -- -- -- -- --
-------------
Script of Card Button "Individual" of Card "Ground Trace"
-------------
-- -- -- -- -- -- --
on mouseUp
  global plotAll
  put false into plotAll
  set hilite of me to true
  set hilite of cd btn "Continuous" to false
end mouseUp
-- -- -- -- -- -- --
```

APPENDIX F: MAJOR FIELD SCRIPTS

Inclusion of all of the field scripts was prohibitive. The first two scripts listed represent a generalized version of the majority of the fields. The remainder are significant enough that their inclusion was necessary. Wherever possible, scripts of similar fields on a specific card have been normalized.

Script of Card Field "< Field Name >" of Card "< Card Name >"

```
-- -- -- -- -- --
on mouseEnter
  select text of me
end mouseEnter
-- -- -- -- -- --
on returnInField
  select text of cd fld "< Next Field Name"
end returnInField
-- -- -- -- -- --
on closeField
  global Error
  if  < Error Condition > then
    answer "Invalid entry! Try again."
    put true into Error
  else
    put false into Error
  end if
end closeField
-- -- -- -- -- --
```

Script of Card Field "Description" of Card "< Card Name >"

```
-- -- -- -- -- --
on mouseUp
  hide me
end mouseUp
-- -- -- -- -- -- --
```

Script of Card Field "Uplink EIRP" of Card "Link Info"

```
-- -- -- -- -- --
on mouseEnter
  select text of me
end mouseEnter
-- -- -- -- -- --
on returnInField
  select text of cd fld "Sat 1 G/T"
end returnInField
-- -- -- -- -- --
```

```
on tabInField
  select text of cd fld "Sat 1 G/T"
end tabInField
-- -- -- -- -- --
on closeField
  global Error,EIRPUp,XmitPwrUp,PwrUp,EOLReserveUp,NumCarriers
  global OutputBOUp,FeederLossUp,XmitLineLossUp,MaintMarginUp
  global PointingLossUp,PointingLossSatMotionUp,XmitAntGain
  put zero into EIRPUp
  put zero into XmitPwrUp
  put zero into XmitAntGain
  put zero into PwrUp
  put zero into EOLReserveUp
  put zero into NumCarriers
  put zero into OutputBOUp
  put zero into FeederLossUp
  put zero into XmitLineLossUp
  put zero into MaintMarginUp
  put zero into PointingLossUp
  put zero into PointingLossSatMotionUp
  if target is not a number then
    answer "Invalid Eirp! Try again."
    put true into Error
    select text of me
  else if abs(target) > 500 then
    answer "Invalid Eirp! Try again."
    put true into Error
    select text of me
  else
    put false into Error
  end if
end closeField
-- -- -- -- -- --
-------------
Script of Card Field "Downlink G/T" of Card "Link Info"
-------------
-- -- -- -- -- --
on mouseEnter
  select text of me
end mouseEnter
-- -- -- -- -- --
on returnInField
  select text of cd fld "Uplink EIRP"
end returnInField
-- -- -- -- -- --
on closeField
  global RcvrNoiseTemp,RcvrAntGain,PointingLoss,MaintMargin,GTDown
  global Error
  put zero into RcvrNoiseTemp
  put zero into RcvrAntGain
  put zero into PointingLossDown
```

```
  put zero into MaintMarginDown
  put zero into GTDown
  if target is not a number then
   answer "Invalid G/T! Try again"
   put true into Error
   select text of me
  else
   put false into Error
  end if
end closeField
-- -- -- -- -- -- --
-------------
Script of Card Field "Sat 1 EIRP" of Card "Link Info"
-------------
-- -- -- -- -- -- --
on mouseEnter
  select text of me
end mouseEnter
-- -- -- -- -- -- --
on returnInField
  select text of cd fld "Downlink G/T"
end returnInField
-- -- -- -- -- -- --
on closeField
  global Error,EIRPDown,XmitPwrDown,EOLReserveDown,OutputBODown
  global FeederLossDown,SatOffCenterLoss,PointingErrorLoss
  global PwrDown,SatXmitAntGain
  put zero into EIRPDown
  put zero into XmitPwrDown
  put zero into EOLReserveDown
  put zero into OutputBODown
  put zero into FeederLossDown
  put zero into SatOffCenterLoss
  put zero into PointingErrorLoss
  put zero into PwrDown
  put zero into SatXmitAntGain
  if target is not a number or abs(target) > 500 then
   answer "Invalid Eirp! Try again."
   put true into Error
   select text of me
  else
   put false into Error
  end if
end closeField
-- -- -- -- -- -- --
-------------
Script of Card Field "Sat 1 G/T" of Card "Link Info"
-------------
-- -- -- -- -- -- --
on mouseEnter
  select text of me
```

```
end mouseEnter
-- -- -- -- -- --
on returnInField
  select text of cd fld "Sat 1 EIRP"
end returnInField
-- -- -- -- -- --
on closeField
  global SatRcvrNoiseTemp,SatRcvrAntGain,SatOffCenterLoss
  global PointingErrorLoss,GTUp,Error
  put zero into SatRcvrNoiseTemp
  put zero into SatRcvrAntGain
  put zero into SatOffCenterLoss
  put zero into PointingErrorLoss
  put zero into GTUp
  if target is not a number then
    answer "Invalid G T! Try again."
    put true into Error
  else
    put false into Error
  end if
end closeField
-- -- -- -- -- --
---------------
Script of Card Field "Xmit Power" of Card "EIRP Parameters"
---------------
-- -- -- -- -- --
on mouseEnter
  select text of me
end mouseEnter
-- -- -- -- -- --
on returnInField
  select text of cd fld "Ant Gain"
end returnInField
-- -- -- -- -- --
on closeField
  global Error,XmitType
  global EIRPUp,XmitPwrUp,PwrUp,EOLReserveUp,NumCarriers
  global OutputBOUp,FeederLossUp,XmitLineLossUp,MaintMargin
  global PointingLoss,PointingLossSatMotionUp
  global EIRPDown,XmitPwrDown,EOLReserveDown,OutputBODown
  global FeederLossDown,SatOffCenterLoss,PointingErrorLoss
  global PwrDown,SatXmitAntGain
  if XmitType is Satellite then
    put zero into XmitPwrDown
    put zero into EOLReserveDown
    put zero into OutputBODown
    put zero into FeederLossDown
    put zero into SatOffCenterLoss
    put zero into PointingErrorLoss
    put zero into PwrDown
  else
```

```
    put zero into XmitPwrUp
    put zero into PwrUp
    put zero into EOLReserveUp
    put zero into NumCarriers
    put zero into OutputBOUp
    put zero into FeederLossUp
    put zero into XmitLineLossUp
    put zero into MaintMarginUp
    put zero into PointingLossUp
    put zero into PointingLossSatMotionUp
  end if
  if target is not a number then
    answer "Invalid entry! Try again."
    put true into Error
  else
    put false into Error
  end if
end closeField
-- -- -- -- -- -- --
-------------
Script of Card Field "Sys Noise Temp" of Card "G/T Parameters"
-------------
-- -- -- -- -- -- --
on mouseEnter
  select text of me
end mouseEnter
-- -- -- -- -- -- --
on returnInField
  select text of cd fld "Ant Gain"
end returnInField
-- -- -- -- -- -- --
on closeField
  global SatRcvrNoiseTemp,SatRcvrAntGain,SatOffCenterLoss
  global PointingErrorLoss,GTUp,RcvrType,Error
  global RcvrNoiseTemp,RcvrAntGain,PointingLoss,MaintMargin,GTDown
  if target is not a number or target < 0 then
    answer "Invalid entry! Try again."
    put true into Error
  else
    put false into Error
    if RcvrType is "Ground" then
      put zero into PointingLossDown
      put zero into MaintMarginDown
    else
      put zero into SatOffCenterLoss
      put zero into PointingErrorLoss
    end if
    if target is not a number then
    end if
  end if
end closeField
```

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